(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
1 March 2007 (01.03.2007)

PCT

(10) International Publication Number
WO 2007/025290 A3

(51) International Patent Classification:
*A61F 2/02* (2006.01) *A61F 5/00* (2006.01)

(21) International Application Number:
PCT/US2006/033687

(22) International Filing Date: 28 August 2006 (28.08.2006)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/712,004 26 August 2005 (26.08.2005) US

(71) Applicants *(for all designated States except US)*: **ISTO TECHNOLOGIES, INC.** [US/US]; 1155 Olivette Executive Parkway, Suite 200, St. Louis, Missouri 63132 (US). **ZIMMER, INC.** [US/US]; 345 East Main, Warsaw, IN 46580 (US).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **GAGE, Gary** [US/US]; 15415 Vineyard Lane, Chesterfield, Missouri 63017 (US). **ADKISSON, H., Davis, IV** [US/US]; 1018 N. Harrison, St. Louis, MO 63122 (US). **BLANCHARD, Cheryl, R.** [US/US]; 1618 S. Woodfield Trail, Warsaw, IN 46580 (US).

(74) Agents: **ZACKSON, Saul, L.** et al.; BIOTACTICA, LLC, P.O. Box 16022, St. Louis, MO 63105 (US).

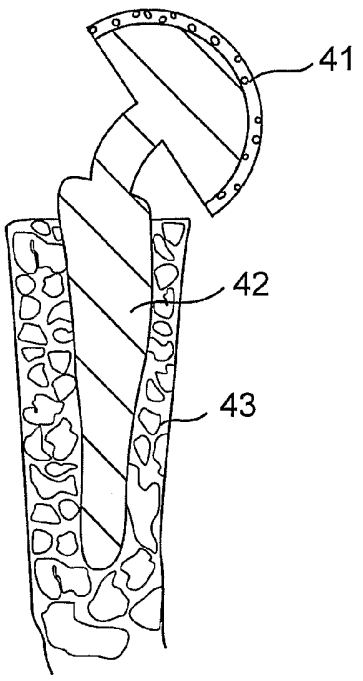
(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LV, LY, MA, MD, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

**Published:**
— *with international search report*

*[Continued on next page]*

(54) Title: IMPLANTS AND METHODS FOR REPAIR, REPLACEMENT AND TREATMENT OF JOINT DISEASE




(57) Abstract: Implants comprising cartilage and trabecular metal, and methods of making the implants are disclosed. Further disclosed are therapeutic uses of the implants, which include methods of treatment or repair of an chondral or osteochondral defect, such as a chondral or osteochondral injury, lesion or disease. An implant comprises cartilage or chondrocytes and a subchondral base comprising trabecular metal. An implant can comprise a geometric shape such as a cylinder or an anatomical shape such as a condyle, and can be used in conjunction with a positioning structure.

WO 2007/025290 A3

— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments*

**(88) Date of publication of the international search report:**
18 October 2007

*For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*

# IMPLANTS AND METHODS FOR REPAIR, REPLACEMENT AND TREATMENT OF JOINT DISEASE

Gary Gage, H. Davis Adkisson, and Cheryl R. Blanchard, inventors

## CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority from U.S. Provisional Application Serial No. 60/712,004 filed on August 26, 2005, which is incorporated herein by reference in its entirety.

## BACKGROUND

[0002] Joint disease, defect, and injury are leading causes of pain and disability in the adult population. The morbidity associated with joint disease, defect, and injury and their spectrum of associated disorders are responsible for significant health care, economic and social costs. Current treatments for repairing or ameliorating a joint disease, defect, or injury, for example an osteochondral injury in which articular cartilage and underlying bone are damaged, can be expensive, inefficacious, painful, or lengthy. Alternative treatments are, therefore, needed.

## SUMMARY

[0003] In view of these and related unmet needs, the present teachings disclose implants which can be used in the treatment, repair and/or partial or full replacement of a chondral or osteochondral defect, such as a chondral or osteochondral disease, defect, injury or lesion. The present teachings also provide methods of forming the implants, as well as methods of treating a chondral or osteochondral defect or injury in a patient in need of treatment, using implants as disclosed herein.

[0004] In various embodiments, an implant of the present teachings comprises cartilage and a subchondral base comprising trabecular metal, which can be a subchondral base

comprising at least one trabecular metal component. In certain alternative embodiments, an implant comprises chondrocytes and a subchondral base comprising trabecular metal, which can be a subchondral base comprising at least one trabecular metal component. A trabecular metal used in an implant comprises at least one metal, which can be, in various aspects, tantalum, niobium, stainless steel, a chromium-cobalt alloy or titanium. In some aspects, a chromium-cobalt alloy can be a chromium-cobalt molybdenum alloy. Furthermore, a trabecular metal comprises a plurality of pores. A plurality of pores can have, in some aspects, a median diameter of from about 3 microns to about 800 microns. In addition, in certain aspects a subchondral base can further comprise at least one porous surface layer which comprises a plurality of pores of median diameter from about 3 microns to about 800 microns. In these aspects, the trabecular metal can have a "graded" porosity, i.e., the median diameter of the plurality of pores of a surface layer can be different from that of the plurality of pores comprising the core of the trabecular metal. Accordingly, in various configurations, a porous surface layer can comprise a plurality of pores of median pore diameter of from about 100 microns to about 800 microns, or, in alternative configurations, a porous surface layer can comprise a plurality of pores of median pore diameter of from about 3 microns to about 20 microns.

[0005] In some configurations of an implant, a subchondral base can comprises at least two surfaces. In these configurations, one surface can comprise trabecular metal having a plurality of pores, wherein the pores have a median pore diameter of from about 100 microns to about 800 microns, while a second surface can be a cartilage-adherent surface. In some aspects of these configurations, a cartilage-adherent surface (i.e., a surface adhesive to cartilage and/or chondrocytes) can comprise a plurality of pores having a median pore diameter of from about 3 microns to about 20 microns. Alternatively, a cartilage-adherent surface can comprise a cartilage adhesive, or a cartilage-adherent surface can comprise both a plurality of pores having a median pore diameter of from about 3 microns to about 20 microns as well as a cartilage adhesive. In various aspects of these configurations, a cartilage adhesive can comprise tissue trans-glutaminase, hyaluronic acid, collagen type I, collagen type II, a chemically cross-linked collagen, fibrin, albumin, gelatin, elastin, silk, demineralized bone matrix, polyethylene oxide, polyethylene glycol, polyvinyl alcohol, polypropylene fumarate or a combination thereof (Jurgensen et al., J. Bone and Joint Surg. 79A: 185-193, 1997; US Patent 6,893,466 to Trieu; US Patent 6,835,277 to Goldberg et al.) or a hydrogel. Furthermore, a cartilage adhesive can also be adhesive towards chondrocytes.

In various aspects, a vertebrate-derived component of a cartilage adhesive, such as tissue trans-glutaminase, hyaluronic acid, collagen type I, collagen type II, fibrin, albumin, gelatin, or elastin, or demineralized bone matrix, can be autologous, allogeneic, or xenogeneic to a mammalian recipient of an implant, such as a human patient in need of treatment. Furthermore, a protein or polypeptide component of a cartilage adhesive such as tissue trans-glutaminase, hyaluronic acid, collagen type I, collagen type II, fibrin, albumin, gelatin, or elastin, can be obtained from a naturally-occurring source such as an animal or human donor, or can be produced using molecular biological methods well known to skilled artisans, such as expression of a gene or cDNA encoding the protein in transformed or transfected cells (see, e.g., Sambrook, J., et al., Molecular Cloning: A Laboratory Manual, 3rd ed. Cold Spring Harbor Laboratory Press, Cold Spring Harbor, NY, 2001).

[0006] In some configurations, a region of a subchondral base comprising pores having a median pore diameter of about 100 microns to about 800 microns can provide a surface which can promote bone attachment and ingrowth, while a region comprising a cartilage-adherent surface can provide a surface which can promote chondrocyte and/or cartilage attachment and growth. In various configurations, a cartilage-adherent surface can be a region of a subchondral base comprising a plurality of pores having a median pore diameter of about 3 microns to about 20 microns, a cartilage adhesive, or a combination of a plurality of pores and a cartilage adhesive, and can comprise trabecular metal or a different material, such as a polymer. In certain configurations, an implant can further comprise a non-trabecular metal material which provides a surface for chondrocyte or cartilage attachment, such as, in non-limiting example, a chondrocyte-adherent ceramic or plastic. In addition, in some configurations, a trabecular metal component of an implant can have a geometry that promotes retention of chondrocytes, such as barbs, ridges or hooks.

[0007] In various aspects, the trabecular metal of an implant can comprise metal having a sintered, porous texture such as sintered, porous titanium or porous tantalum. Furthermore, the trabecular metal can be sintered and/or cancellous-structured. In addition, in some configurations, a porous surface layer can include a biocompatible porous metal sheet, such as a porous titanium sheet. In addition, in some configurations, a porous surface layer can include an absorbable biocompatible material such as polylactic/polyglycolic acid (PLA/PGA).

[0008] In various configurations of the present teachings, cartilage comprised by an implant can be juvenile cartilage, a cartilage formed in vitro such as neocartilage described in Adkisson, H.D. et al., Clin. Orthop. 391S: S280-S294, 2001; and US Patents 6,235,316 and 6,645,316 to Adkisson, minced cartilage, minced juvenile cartilage and/or devitalized cartilage. In various aspects, the cartilage can comprise chondrocytes. Chondrocytes comprising an implant can be, in various aspects, chondrocytes grown either in contact with a trabecular metal, separately from the trabecular metal, or in a combination of growth apart from the trabecular metal then in contact with the trabecular metal. The contact between the chondrocytes and the at least one trabecular metal can be established either in vivo or in vitro, and subsequent growth can occur in vivo, in vitro, or in a combination thereof. Chondrocytes in contact with trabecular metal can be, in some configurations, chondrocytes adherent to the trabecular metal. Chondrocytes used in various configurations of the implants, including chondrocytes comprised by cartilage, can be chondrocytes allogeneic to, autologous to, and/or xenogeneic to a mammalian recipient such as a human patient. A donor of the chondrocytes can be, in various configurations, a cadaver no older than about fourteen years of age at time of death. Accordingly, as used herein, the terms "juvenile chondrocytes" refers to chondrocytes obtained from a human donor less than about fourteen years of age at time of donation. Similarly, the term "juvenile cartilage" as used herein refers to cartilage formed from such chondrocytes. In some embodiments, chondrocytes comprising an implant can be chondrocytes differentiated from chondrocyte precursor cells such as mesenchymal stem cells, for example as described in US Patent 5,811,094 to Caplan et al.

[0009] In various aspects of the present teachings, an implant can comprise cartilage affixed to a subchondral base comprising trabecular metal. A subchondral base of these aspects can comprise a biocompatible metal sheet. A biocompatible metal sheet can be a biocompatible porous metal sheet or a biocompatible non-porous metal sheet An attachment between cartilage and a subchondral base of an implant can include, in non-limiting example, one or more sutures, one or more biocompatible adhesives, one or more biocompatible absorbable fasteners, a chemical cross-link, a polymer formed from subunits polymerized at a cartilage/trabecular metal juncture, and/or one or more laser welds. In these aspects, a biocompatible adhesive can include at least one biocompatible macromolecular adhesive such as a fibrin-based adhesive, a collagen-based adhesive or a combination thereof, and a biocompatible absorbable fastener can be, without limitation, a staple, a dart, a pin or a tack,

and can comprise a biocompatible material such as, without limitation, polylactic/polyglycolic acid (PLA/PGA).

[0010] In various configurations, an implant of the present teachings can be substantially cylindrical in shape, or can be substantially a pyramidal wedge or substantially a frustoconical "mushroom" in shape (see, e.g., US Patent 6,743,232 to Overaker et al.) Alternatively, an implant can have a shape more closely approximating an anatomical shape, such as that of a joint or a bone/joint combination, such as a shape of a human condyle, a human hemi-condyle, a human acetabular cup or a human femoral head.

[0011] Embodiments of the present teachings also include methods of forming an implant comprising cartilage and a subchondral base comprising trabecular metal. Various configurations of these methods comprise growing a population of chondrocytes in vitro, and contacting the population of chondrocytes with a subchondral base comprising trabecular metal. In these embodiments, contacting a population of chondrocytes with a trabecular metal can include coupling or attaching the chondrocytes to the trabecular metal. In some aspects, growing a population of chondrocytes in vitro can comprise growing the chondrocytes in a matrix. In these aspects, the matrix can later be attached to a subchondral base comprising trabecular metal. In various aspects, the chondrocytes can be juvenile chondrocytes, and the trabecular metal can comprise a porous surface as described herein for an implant. In some configurations, chondrocytes can be grown in a scaffold-free environment. The chondrocyte population can also be grown in contact with a subchondral base comprising trabecular metal. In these methods, contact between the chondrocytes and the subchondral base can be initiated prior to chondrocyte growth, during chondrocyte growth, or after chondrocyte growth. The chondrocyte growth can occur in vivo or in vitro. Accordingly, the contacting between a trabecular metal and the chondrocytes can occur subsequent to the growing, and/or simultaneously with the growing. As a result, the juvenile chondrocytes can grow in contact with the trabecular metal, or without contacting the trabecular metal.

[0012] In some configurations, methods of forming an implant can comprise growing chondrocytes in the presence of a trabecular metal component such that the chondrocytes adhere to a surface of the component. In some alternative configurations, methods of forming an implant can comprise coupling a cartilage tissue component to a surface of a trabecular metal component.

[0013] In certain configurations, methods of forming an implant include attaching cartilage to a subchondral base. The attaching can comprise applying one or more sutures, a biocompatible adhesive, and/or an absorbable fastener to the cartilage and/or the subchondral base. A biocompatible adhesive can be, in non-limiting example, a macromolecule such as a fibrin, a collagen, or a combination thereof. An absorbable fastener can be, in non-limiting example, a staple, a dart or a tack. The attaching can be accomplished by methods well known to skilled artisans.

[0014] In some configurations, a method of these embodiments can include applying a biocompatible adhesive, such as a fibrin, to a subchondral base comprising trabecular metal, prior to contacting the base with a population of chondrocytes such as juvenile chondrocytes. In some alternative configurations, a method of these embodiments can include applying a biocompatible adhesive, such as a fibrin glue, to a population of chondrocytes prior to contacting the subchondral base with the chondrocytes. In these configurations, the fibrin can be fibrin autologous to a mammalian recipient of the implant, fibrin allogeneic to a mammalian recipient of the implant, fibrin xenogeneic to a mammalian recipient of the implant, synthetic fibrin, or a combination of two or more of these types of fibrin. Furthermore, trabecular metal comprised by a subchondral base can comprise a porous surface as described for implants herein. In addition, in some aspects, a method of these embodiments can further comprise applying to a surface of a subchondral base a biocompatible absorbable polymer, such as polylactic/polyglycolic acid (PLA/PGA). The surface can be, in some aspects, a porous surface of the subchondral base.

[0015] Methods of forming an implant comprising cartilage and a subchondral base can include, in various configurations, growing a population of juvenile chondrocytes in vitro in a scaffold-free environment, and contacting the population of juvenile chondrocytes with a trabecular metal subsequent to the growing.

[0016] Some embodiments of the present teachings include methods of treating joint disease, defect or injury in a patient in need thereof. These methods can include introducing, into a patient in need, an implant of the present teachings. Introduction of an implant can comprise insertion or attachment of the implant into bone tissue of a recipient. Accordingly, in some configurations, a method can comprise introducing an implant comprising both cartilage and a subchondral base comprising trabecular metal as described herein into a patient at a site of joint disease, defect or injury. In some alternative configurations, a method

can comprise introducing a subchondral base comprising trabecular metal into a patient, and attaching to base a component comprising cartilage or chondrocytes, including juvenile chondrocytes. In certain configurations, the subchondral base can be configured to receive chondrocytes such as juvenile chondrocytes comprised by neocartilage. In some aspects of these configurations, the former component can further comprise a surface which promotes chondrocyte attachment, such as a porous surface having a plurality of pores of median diameter of about 3 microns to about 20 microns, a biocompatible macromolecule, or a combination thereof. In some configurations, the present teachings disclose methods comprising introducing into a patient a subchondral base comprising trabecular metal. In these configurations, the subchondral base can be configured for receiving chondrocytes. These methods further comprise adding, adjacent to subchondral base, chondrocytes such as juvenile chondrocytes which have been grown in vitro, thereby forming an implant of the present teachings. The chondrocytes in certain aspects can comprise juvenile chondrocytes grown in vitro but not organized into cartilage tissue, or can be juvenile chondrocytes comprised by neocartilage, and the subchondral base which is configured for receiving chondrocytes can comprise a porous surface region having a plurality of pores of median diameter of about 3 microns to about 20 microns, a biocompatible macromolecule, or a combination thereof. The subchondral base can further comprise a region having a plurality of pores of median diameter of about 100 microns to about 800 microns.

[0017] In some configurations of these embodiments, a method can further include introducing a non-trabecular metal positioning structure to a recipient patient. Such a positioning structure can aid in the positioning or physical stability of an implant in the patient. In various configurations, a positioning structure can comprise a biocompatible metal or a biocompatible polymer. In configurations of these embodiments, a trabecular metal portion of an implant can be configured to attach to the positioning structure, and/or the positioning structure can be configured to attach to the subchondral base. In certain aspects, the positioning structure can be configured for engaging the bone, and can be, in non-limiting example, a screw, a cylinder, a plat, a rod, or a washer. In addition, in various aspects, a positioning structure can also comprise trabecular metal, and/or can comprise a material other than trabecular metal, such as, in non-limiting example, a biocompatible polymer, or a metal that is non-trabecular.

[0018] In some configurations, an implant described herein can be used in the manufacture of a medicament for treatment of joint disease, repair, or injury.

[0019] Embodiments of the present teachings also encompass a kit comprising components of a disclosed implant. In these embodiments, a kit can include at least chondrocytes or cartilage, and a trabecular metal component of an implant. In some aspects of a kit, the chondrocytes or cartilage and the trabecular metal component can be packaged in separate containers, while in other aspects, a kit can comprise an implant comprising both cartilage or chondrocytes and a trabecular metal component of an implant. In some aspects, additional kit components can include culture medium for growing or maintaining chondrocytes or cartilage *in vitro*. In some configurations, a kit can further include instructions and/or reagents which can be used to assemble an implant, and/or tools and equipment which can aid in the assembly of an implant and/or installation of an implant into a recipient, such as, in non-limiting example, fasteners such as suturing thread, a staple, a dart, or a tack, such as a surgical grade staple, dart or tack,

## BRIEF DESCRIPTION OF THE FIGURES

[0020] FIG. 1 illustrates replacement of a femoral head in a patient suffering from a femoral head fracture with an implant..

[0021] FIG. 2 illustrates attachment of neocartilage to a subchondral base in vitro.

[0022] FIG. 3 illustrates a screw-shaped positioning structure inserted into bone, and attachment of an implant to the structure.

[0023] FIG. 4 illustrates a trabecular metal base having receiving screw threads, a positioning structure comprising a screw and a "platform" to which neocartilage is attached, and formation of an implant comprising the trabecular metal and the positioning structure.

[0024] FIG. 5 illustrates attachment of cartilage to a subchondral base comprising trabecular metal.

[0025] FIG. 6 illustrates seeding of cells onto a trabecular metal component of a suchondral base.

[0026] FIG. 7 illustrates a variety of implant shapes useful for chondral or osteochondral repair.

[0027] FIG. 8 illustrates an anatomically-shaped implant as inserted into bone.

## DETAILED DESCRIPTION

[0028] The present teachings disclose implants which can be used in the treatment of joint disease, defect or injury, including chondral or osteochondral disease, as well as methods of forming the implants. In some alternative embodiments, the present teachings disclose methods of treating a patient in need of treatment with the implants.

[0029] In various configurations, an implant of the present teachings comprises a combination of cartilage and a subchondral base comprising trabecular metal. "Cartilage," as used herein, encompasses articular cartilage, hyaline cartilage, neocartilage (Adkisson, H.D. et al., Clin. Orthop. 391S: S280-S294, 2001; and US Patents 6,235,316 and 6,645,316), devitalized cartilage, auricular cartilage, cartilage comprising genetically modified chondrocytes, cartilage from an autogenous source, cartilage from an allogenic source, cartilage from a xenogeneic source, juvenile cartilage, or a combination thereof. In some configurations, cartilage can also comprise chondrocytes differentiated from precursor cells such as mesenchymal stem cells. "Trabecular metal," as used herein, encompasses biocompatible, porous metal compositions, such as a porous tantalum biomaterial. Descriptions of trabecular metal, as well as various methods of making trabecular metal of various pore sizes and using trabecular metal in applications such as prosthetic devices are described in references such as Bobyn et al., J. Biomed. Mater. Res. 16: 571-581, 1982; Bobyn et al., J. Bone Joint Surg. Br. 81-B: 907-14, 1999; Bobyn et al., J. Arthroplasty 14: 347-354, 1999; Black, Clinical Materials 16: 167-173 (1994); Hacking et al., J. Biomed. Mater. Res. 52: 631-638, 2000; US Patent 4863475 to Andersen et al.; US Patent 4479271 to Bolesky et al.; US Patent 4863474 to Brown et al.; US Patents 5535810 and 6544472 to Compton et al.; US Patent 5219363 to Crowninshield et al.; US Patents 5236457, 5387243 and 5571187 to Devanathan; US Patents 5504300, 5672284 and 5723011 to Devanathan et al.; US Patent 4997444 to Farling; US Patent 4660755 to Farling et al.; US Patent 6740186 to Hawkins et al.; US Patents 4997445 and 6797006 to Hodorek; US Patent 5080674 to Jacobs et al.; US Patents 5734959 and 5926685 to Krebs et al.; US Patent 4566138 to Lewis et al.; US Patent 6417320 to Otto et al.; US Patent 5443512 to Parr et al.; US Patents 6685987 and 6395327 to Shetty; US Patents 5198308, 5323954 and 5443510 to Shetty et al.; US Patent 5496375 to Sisk et al.; US Patents 6336930 and 6447514 to Stalcup et al.; US Patent 5879398 to Swarts et al.; US Patent 5456828 to Tersi et al.; US Patent 5639280 to Warner et al.; and US Patents 5018285 and 5013324 to Zolman et al.

[0030] In various configurations, an implant of the present teachings comprises a combination of chondrocytes and a subchondral base comprising trabecular metal. The chondrocytes can be, in some aspects, chondrocytes included in hyaline cartilage such as, without limitation, neocartilage. In other aspects, the chondrocytes can be chondrocytes with the potential to generate hyaline cartilage, but not organized into histologically recognizable cartilage. In some aspects of these configurations, a chondrocyte donor can be a cadaver. Hence, the chondrocytes can be cadaver chondrocytes. These chondrocytes can be grown in vitro using cell culture techniques known to skilled artisans, for example as described in US Patent Application 10/956,971 of Milliman and Adkisson. As used herein, the term "cadaver chondrocytes" refers to viable chondrocytes originally comprised by a human cadaver, as well as clonal descendants of such chondrocytes, such as chondrocytes grown *in vitro*. Cadaver chondrocytes for use in the various aspects of the present teachings can be obtained from tissues comprising chondrocytes from a cadaver, such as cartilage tissue. Such tissues can be dissected from a cadaver using standard dissection methods well known to skilled artisans. The cartilage tissue utilized in the present teachings can comprise hyaline cartilage, or chondrocytes with the potential to generate hyaline cartilage, such as, for example, articular joint cartilage, tracheal cartilage, laryngeal cartilage, costal cartilage, epiphyseal plate cartilage, and combinations thereof. In various aspects, the cartilage tissue or chondrocytes can be knee joint cartilage or chondrocytes, hip joint cartilage or chondrocytes, or cartilage or chondrocytes from any other articular joint. Viable chondrocytes can be obtained from cartilaginous tissues in a donor cadaver any time after donor death of the donor, for example, for up to about two weeks after death of the donor. Accordingly, in some configurations, the time interval from the time of death of a donor (as determined, for example, by a physician or a coroner) to the time of dissection of cartilage tissue from the donor can be any time from immediately following a pronouncement of death, to about two weeks following death, such as, without limitation, about one hour, greater than 24 hours, about two days, about three days, about four days, about five days, about six days, about seven days, about eight days, about nine days, about ten days, about eleven days, about twelve days, about thirteen days, about fourteen days after death, or longer. In addition, a donor cadaver can be of any chronological age at time of death. For example, a donor cadaver can be, at time of death, about fourteen years old or younger. A donor cadaver need not be a familial member of a recipient, or be otherwise matched immunologically. Without being limited by theory, it is believed that chondrocytes are an "immunologically privileged" cell

type, so that chondrocytes transplanted to an allogeneic recipient are not subject to rejection by the recipient's immune system.

[0031] In the present teachings, cartilage tissue can be removed from a cadaver using any surgical or dissecting techniques and tools known to skilled artisans. Following cartilage removal from a cadaver, the cartilage tissue can be minced, dissociated into single cells or small groups of cells, and/or placed into tissue or cell culture and expanded using standard techniques and apparatuses well known to skilled artisans. Such techniques and apparatuses are described in the references such as, for example, Feder, J. et al. in: Tissue Engineering in Musculoskeletal Clinical Practice. American Academy of Orthopaedic Surgeons, 2004; Adkisson, H.D. et al., Clin. Orthop. 391S:S280-S294, 2001; and US Patents 6,235,316 and 6,645,316 to Adkisson.

[0032] Cadaver chondrocytes used in the various embodiments of the present teachings are all cadaver chondrocytes which express type II collagen. In addition, in some aspects, cadaver chondrocytes can comprise chondrocytes expressing other molecular markers such as a high molecular weight sulfated proteoglycan, such as, for example, chondroitin sulfate (Kato, Y., and Gospodarowicz, D., J. Cell Biol. 100: 477-485. 1985). Presence of such markers can be determined using materials and methods well known to skilled artisans, such as, for example, antibody detection and histological staining.

[0033] In some configurations, cadaver cartilage tissue can be extracted from a cadaver. The cartilage tissue can then be dissociated into individual cells (or small clusters of cells), grown in vitro, and can then be combined with a subchondral base comprising trabecular metal, thereby forming an implant of the present teachings. Accordingly, in some aspects, the chondrocytes can be included in neocartilage. In vitro expansion of chondrocytes, and formation of neocartilage, can be accomplished using cell culture techniques and apparatuses well known to skilled artisans, such as culture methods for neocartilage described in US Patents 6,235,316 and 6,645,316 to Adkisson, and other general laboratory manuals on cell culture such as Sambrook, J. et al., Molecular Cloning: a Laboratory Manual (Third Edition), Cold Spring Harbor Laboratory Press, Cold Spring Harbor, NY, 2001; and Spector, D.L., et al., Culture and Biochemical Analysis of Cells, Cold Spring Harbor Laboratory Press, Cold Spring Harbor, NY 1998.

[0034] In some configurations, a cell culture can include trabecular metal within a cell culture chamber. In these configurations, chondrocytes can grow in direct contact with a

subchondral base of the present teachings, such as a subchondral base comprising trabecular metal as presented herein. Furthermore, the subchondral base can further comprise a cartilage-adherent surface. In various configurations, chondrocytes and/or cartilage can adhere to such a surface. In various aspects, chondrocytes adhered to such surfaces can proliferate and/or form cartilage such as neocartilage. Accordingly, as used herein, a "cartilage-adherent surface" is a surface of a biocompatible material to which cartilage can adhere. Similarly, as used herein, a "chondrocyte-adherent surface" is a surface of a biocompatible material to which chondrocytes can adhere. Non-limiting examples of cartilage- and chondrocyte adherent surfaces include a porous surface such as a trabecular metal surface comprising pores of median diameter from about 3 microns to about 20 microns, a plastic or ceramic surface comprising a cartilage adhesive or a chondrocyte adhesive, or a porous surface comprising pores of median diameter from about 3 microns to about 20 microns and a cartilage adhesive or chondrocyte adhesive. As used herein, the terms "cartilage adhesive" and "chondrocyte adhesive" refer to molecular species or mixtures of species which promote adhesion of cartilage or chondrocytes to a surface, by acting as a glue and/or by promoting adhesion-forming activity of cells. In various embodiments, a cartilage or chondrocyte adhesive can be used as a glue at the interface between cartilage or chondrocytes and a cartilage- or chondrocyte-adherent surface.

[0035] In certain configurations, cartilage tissue can be harvested from a donor such as a cadaver and placed as explants in a cell culture chamber including a growth medium as disclosed in the above-cited references. In some aspects, a cell culture chamber can further include a subchondral base (which can comprise trabecular metal) and a chondrocyte-adherent surface. In these aspects, chondrocytes can migrate out from the explant and populate the chondrocyte-adherent surface. A subchondral base populated with chondrocytes can be used directly as an implant in a recipient, or can be cultured under conditions which promote chondrocyte or cartilage maintenance or growth, or neocartilage formation as disclosed, for example, in US Patents 6,235,316 and 6,645,316 to Adkisson or US Patent 5,041,138 to Vacanti et al.

[0036] In certain alternative configurations, a cartilage explant can be affixed directly to a subchondral base and a cartilage-adhesive surface to form an implant, using methods and materials disclosed herein, such as, for example, sutures, adhesives, and fasteners.

[0037] In various aspects, chondrocytes adhered to a cartilage-adherent surface can grow and/or form cartilage tissue such as neocartilage. In certain alternative aspects, a surface can comprise a cartilage adhesive such as a fibrin adhesive as described herein. In yet other aspects, a surface can comprise a both a plurality of pores having a median diameter of about 3 microns to about 20 microns and a cartilage adhesive. The surface can comprise, in non-limiting example, trabecular metal, plastic such as cell culture plastic or an absorbable biocompatible material such as polylactic/polyglycolic acid (PLA/PGA). In addition, in various aspects, chondrocytes such as juvenile chondrocytes can be grown separately from a subchondral base.

[0038] In some embodiments of the present teachings, a method of treating a patient can comprise transferring an implant into a recipient patient. In other embodiments, a subchondral base component of an implant can be implanted into a recipient patient, for example by surgically attaching the subchondral base to a bone, followed by addition of chondrocytes and/or cartilage adjacent to the subchondral base. In some configurations, a method can further comprise attaching a positioning structure to a patient, then attaching an implant to the positioning structure. As used herein, the term "positioning structure" refers to a structure configured for supporting, positioning and/or maintaining the position of an implant of the present teachings or a portion thereof in a recipient such as a human patient. In non-limiting example, a positioning structure can be a screw or a cylinder which attaches to an aperture introduced into a patient's bone. A positioning structure of these configurations can comprise a biocompatible material such as, for example, a biocompatible polymer or a biocompatible metal.

[0039] In certain configurations, a positioning structure can be configured for engaging the bone. In these configurations, a positioning structure can be introduced to a bone of a subject. A subchondral base can then be attached to the positioning structure. Chondrocytes or cartilage, such as, in non-limiting example, devitalized cartilage or neocartilage, can then be attached to the subchondral base. Alternatively, in some configurations, a positioning structure can be introduced into a patient, for example by attaching to a bone an implant comprising both chondrocytes and/or cartilage and a subchondral base comprising trabecular metal can then be attached to the positioning structure.

[0040] Trabecular metal comprised by the implants of the present teaching can comprise any form of trabecular metal that is compatible with viable cells or tissues. In various aspects,

trabecular metal used in an implant can be trabecular metal described in publications such as US Patent 5,282,861 to Kaplan, US Patent 5,456,723 to Steinemann et al., US Patent 6,087,553 to Cohen, or US Patent 6,840,960 to Bubb. In non-limiting examples, the trabecular metal can comprise tantalum, which can be substantially pure tantalum, niobium, titanium, which can be substantially pure titanium, stainless steel, a chromium-cobalt alloy, or a combination thereof. In some aspects, a chromium-cobalt alloy can be a chromium-cobalt-molybdenum alloy. In certain configurations, the trabecular metal can be porous throughout its structure, or substantially porous near the surface, and can comprise, in non-limiting example, a porous surface layer and a core, which can be porous or non-porous. Accordingly, in some configurations, a trabecular metal can include a core comprising a biocompatible material, such as, in non-limiting example, tantalum, niobium, titanium, a chrome-cobalt alloy or a ceramic, and a porous surface which can be, in non-limiting example, a porous titanium sheet or a cancellous-structured titanium layer.

[0041] In some configurations, an implant comprising a subchondral base comprising trabecular metal of the present teachings can further comprise one or more bioactive molecules, such as, in non-limiting example, a transforming growth factor-β family member protein such as a bone morphogenetic protein (BMP), basic fibroblast growth factor (bFGF), or other chondroinductive or osteoinductive molecules. Accordingly, in some aspects, a chondral-adhesive portion of an implant can comprise one or more chondroinductive molecules, while a subchondral base can comprise one or more osteoinductive molecules.

[0042] In some aspects of the present teachings, a surface for attachment of chondrocytes can comprise a plurality of pores. The pores can have a median pore diameter from about 3 microns to about 20 microns. The pores can be substantially homogeneous in diameter, or can be substantially heterogeneous in diameter. In some alternative aspects, the surface can comprise at least one biological macromolecule. A biological macromolecule can be, in some configurations, a macromolecule such as hyaluronic acid, collagen type I, collagen type II or fibrin. In various aspects, fibrin comprised by a surface layer can include fibrin that is autologous to a mammalian recipient of the juvenile chondrocytes, fibrin allogeneic to a mammalian recipient of the juvenile chondrocytes, fibrin xenogeneic to a mammalian recipient of the juvenile chondrocytes, synthetic fibrin, or a combination of two or more of these types of fibrin. In yet other aspects, a surface for attachment of chondrocytes can comprise both a plurality of pores and at least one biological macromolecule or biocompatible polymer. Such surfaces can be prepared using techniques known to skilled

artisans, such as, for example, techniques disclosed in US Patent 6,740,186 to Hawkins. In some aspects, trabecular metal can be coated with or coupled to a biocompatible porous absorbable polymer, such as, for example, PLA/PGA to form a biocompatible surface layer to which chondrocytes can attach. Such a surface layer can promote juvenile chondrocyte growth in vivo or in vitro. In other aspects, trabecular metal can be coated with an osteoconductive or chondroconductive material such as, in non-limiting example, hydroxyapatite or hydroxyapatite-tricalcium phosphate.

[0043] In certain configurations, trabecular metal can be attached to biocompatible porous absorbable polymer such as PLA/PGA to form a reservoir or "cup" into which chondrocytes, cartilage and/or a biocompatible adhesive can be placed. In this connection, US Patent 4,997,445 to Hodorek discloses examples of methods for attaching a polyethylene polymer to a metal base which can be adapted to form the base of an implant of the present teachings.

[0044] In various aspects of the present teachings, trabecular metal comprising a porous surface can be made by any process known to skilled artisans, such as, in non-limiting example, etching methods or sputtering methods. In various aspects of the present teachings, a porous surface layer of a subchondral base used in an implant can comprise metal having a sintered, porous texture such as, for example, sintered, porous, cancellous-structured titanium. In addition, in some configurations, a porous surface layer can include a biocompatible porous metal sheet, such as a porous titanium sheet or a stainless steel sheet. Accordingly, in some configurations, an implant can comprise a trabecular metal which comprises a core material, which may or may not be porous, and a porous covering or sheet. In non-limiting example, the core material can be a chrome-cobalt alloy, such as, without limitation, a chrome-cobalt-molybdenum alloy, tantalum, niobium or titanium.

[0045] In various aspects, a subchondral base comprising trabecular metal can further comprise at least one biological macromolecule, a biocompatible polymer, a biocompatible ceramic, and/or an osteoconductive or chondroconductive materal such as hydroxyapatite or hydroxyapatite-tricalcium phosphate. A biological macromolecule of these aspects can be, without limitation, hyaluronic acid, a transforming growth factor-β family member protein such as a bone morphogenetic protein (BMP), basic fibroblast growth factor (bFGF), or other chondroinductive or osteoinductive molecule. Without being limited by theory, it is believed that a biological macromolecule or biocompatible polymer can promote attachment of

chondrocytes or cartilage to a trabecular metal surface by acting as a carrier and/or an adhesive. It is further believed that a biological macromolecule or biocompatible polymer, such as bioabsorbable polymer such as PLA/PGA can promote chondrocyte expansion when used as a coating of a surface such as a trabecular metal surface.

[0046] In various configurations of the present teachings, juvenile cartilage comprised by an implant can comprise cartilage formed in vitro, such as neocartilage described in Adkisson, H.D. et al., Clin. Orthop. 391S: S280-S294, 2001; and US Patents 6,235,316 and 6,645,316 to Adkisson. Chondrocytes comprising the cartilage can be grown either in contact with a subchondral base, separately from the subchondral base, or in a combination of growth apart from the base then in contact with the base. The contact between the chondrocytes and the subchondral base can be established either in vivo or in vitro, and subsequent growth can occur in vivo, in vitro, or a combination thereof. In non-limiting example, a culture chamber can be established comprising both chondrocytes and trabecular metal, under culture conditions that support formation of neocartilage. The neocartilage can then form directly on the surface of the at least one trabecular metal. The chondrocytes comprising the juvenile cartilage can be chondrocytes allogeneic to a mammalian recipient such as a human patient, or autologous to a recipient.

[0047] In certain aspects of the present teachings, an implant can include cartilage such as neocartilage comprising juvenile chondrocytes grown in contact with a subchondral base, either in vitro or in vivo, and can furthermore include neocartilage from juvenile cartilage attached to the subchondral base. As used herein, "chondrocyte growth" includes expansion of a population of chondrocytes or chondrocyte precursor cells such as mesenchymal stem cells, differentiation of chondrocyte precursor cells into chondrocytes, and/or accumulation and buildup of cartilaginous extracellular matrix during cartilage tissue formation. The attachment can include an attachment between the neocartilage and the base, and can aid in the establishment and/or retention of the shape of an implant. Accordingly, in some aspects, an implant can include at least one suture, which can attach the juvenile cartilage to the base. In non-limiting example, a series of sutures can be used to hold neocartilage to trabecular metal comprised by a subchondral base. Standard suturing instrumentation and techniques well-known to skilled artisans can be used to attach the neocartilage to the at least one trabecular metal. The sutures can be made of any known suture material, such as, for example, an absorbable material such as PLA/PGA. In alternative aspects, cartilage can be attached to a subchondral base using at least one biocompatible adhesive, such as, in non-

limiting example, a fibrin-based adhesive, a collagen-based adhesive or a combination thereof. In yet other aspects, attachment of cartilage to a subchondral base can be effected using at least one absorbable fastener. In these aspects, an absorbable fastener can comprise a biocompatible material such as PLA/PGA, and can be, without limitation, a staple, a dart, or a tack, such as a surgical grade staple, dart or tack. A fastener can be applied to cartilage and a subchondral base using any technique known to skilled artisans. In some configurations, cartilage can be attached to a subchondral base by applying a chemical cross-linker such as, in non-limiting example, an aldehyde cross-linker such as formaldehyde or glutaraldehyde, or a homobifunctional or heterobifunctional cross-linker such as a cross-linker having amine-reactive and thiol reactive moieties, for example sulfosuccinimidyl 4-[N-maleimidomethyl]cyclohexane-1-carboxylate, supplied by Pierce Chemical, Rockford IL.

[0048] In various configurations, an implant of the present teachings can be substantially cylindrical in shape. Cylindrically shaped implants comprising non-autologous chondrocytes can be used, for example, in mosaicplasty-type joint repairs (see, e.g., Minas, T. et al., Orthopedics 20: 525-538, 1997; Marcacci, M., et al., Arthroscopy 21: 462-470, 2005; Christel, P., et al., http://www.maitrise-orthop.com/corpusmaitri/orthopaedic/mo76_mosaicplasty/index.shtml). Alternatively, one or more features of an implant can have a shape more closely approximating an anatomical shape, such as, for example, a feature of a joint. Without limitation, an implant of the present teachings can have, in some aspects, a substantially anatomical shape such as a shape of a human condyle, a hemi-condyle, an acetabular cup or a femoral head.

[0049] The present disclosure also includes methods of forming an implant of the present teachings. These methods comprise growing a population of chondrocytes in vitro, and contacting the population with a trabecular metal comprising a porous surface. In some configurations, the chondrocyte population can be grown in a scaffold-free environment. As used herein, the term "scaffold" refers to a support for chondrocytes or cartilage tissue onto which cells can attach, proliferate, and/or synthesize new tissue, other than a cell culture apparatus such as a plastic cell culture chamber. For example, chondrocytes obtained from a cadaver can be grown to increase cell numbers by about 1000 fold without any trabecular metal in a cell growth apparatus comprising the chondrocytes (e.g., a cell culture flask). The cells, which can be included within neocartilage, can then be attached to a piece of trabecular metal which can be of a shape appropriate for an osteochondral repair in a patient, and

thereby form an implant which can be transplanted to the patient at a site of joint injury, defect or disease.

[0050] In some aspects, a chondrocyte population can be grown in contact with a subchondral base comprising trabecular metal. In these configurations, chondrocytes can be grown in an apparatus comprising the subchondral base. In various aspects of these configurations, the chondrocytes can attach and grow directly on the trabecular metal surface in vitro, and thereby form neocartilage directly on the trabecular metal. A resulting implant can then can then be transplanted to a recipient patient. Furthermore, in these configurations, chondrocytes can form neocartilage on the trabecular metal, and thereby form a layered structure comprising a layer of metal covered by a layer of neocartilage. Accordingly, implants can be formed of various shapes for transplantation into a patient. For example, an implant comprising trabecular metal shaped as an acetabular cup for a hip replacement can be covered on its rounded surface with cartilage by growing juvenile chondrocytes in the presence of the trabecular metal.

[0051] Accordingly, the present disclosure provides methods of treating joint disease, defect, or injury in a patient in need thereof. As used herein, "joint disease, defect or injury" includes physical conditions or diseases which can benefit from cartilage or osteochondral repair, replacement, or augmentation, such as, in non-limiting example, athletic injury, traumatic injury, congenital disorders, osteoarthritis and joint degeneration from aging. These methods include introduction of an implant of the present teachings into a recipient patient in need of treatment. In some embodiments, the methods comprise transplanting an implant comprising cartilage and/or chondrocytes and a subchondral base as described herein into the patient at a site of joint disease, defect or injury. In other embodiments, some methods comprise implanting into a patient an subchondral base comprising trabecular metal, and applying juvenile chondrocytes to the subchondral base subsequent to the implantation. In some configurations, a subchondral base can further comprise a chondrocyte attachment portion as described above. By temporally separating the attachment of the subchondral base to the bone and the attachment of the chondrocytes to the subchondral base, methods of these embodiments can reduce or eliminate trauma to the cells that can be associated with attaching a hard object to a bone of a patient. In additional embodiments, a positioning device can also be introduced into a patient. The positioning device can be attached to an appropriate site in a patient by a health professional such as a surgeon. In non-limiting example, a positioning device can be attached to a bone or introduced into an aperture in the bone. The positioning

device can be configured for the attachment of the at least one trabecular metal base portion. The positioning device can be, in non-limiting example, a screw or a cylinder. A positioning device can comprise any material compatible with a patient's physiology, such as, for example, metal including non-trabecular metal, an absorbable polymer such as polylactic/polyglycolic acid (PLA/PGA) or a non-absorbable polymer. In certain configurations, the subchondral base can be configured to engage the positioning device, for example by comprising an internal screw thread which mates with the screw of the positioning device. Chondrocytes, which can be in the form of neocartilage, can then be applied to the prosthetic device. Alternatively, cartilage and/or chondrocytes can be applied to subchondral base before attaching the latter to the positioning device. In yet other configurations, a positioning device can comprise a surface for attaching chondrocytes and/or cartilage. In these configurations, chondrocytes or cartilage can be attached to the surface; a subchondral base comprising trabecular metal can be inserted into a patient (for example, by insertion of the base into an aperture introduced by a surgeon into a bone of the patient) and the positioning device, including the chondrocytes or cartilage, can then be attached to the subchondral base, thereby forming an implant comprising a subchondral base and chondrocytes and/or cartilage Accordingly, a wide variety of possible combinations comprising a subchondral base, chondrocytes and/or cartilage, and a positioning device are contemplated as within the scope of the present teachings.

## Examples

[0052] Various embodiments of the present teachings can be illustrated by the following non-limiting examples. The following examples are illustrative, and are not intended to limit the scope of the claims. The description of a composition or a method in an example does not imply that a described article or composition has, or has not, been produced, or that a described method has, or has not, been performed, irrespective of verb tense.

### Example 1

[0053] This example illustrates replacement of a femoral head in a patient suffering from a femoral head fracture with an implant.

[0054] In this example, as shown in Figure 1, a porous femoral head prosthesis (2) comprising a rounded surface comprising pores of median diameter of about 10 microns, is

placed in an in vitro cell growth chamber. Juvenile chondrocytes are seeded onto the rounded surface, and cultured as described in Adkisson, H.D. et al., Clin. Orthop. 391S: S280-S294, 2001; and US Patents 6,235,316 and 6,645,316). The chondrocytes are permitted to grow until a layer of neocartilage (1) forms on the surface of the prosthesis (Figure 1a). A surgeon then drives a spike-shaped subchondral base (3) comprising trabecular metal into the proximal femur (4) of the patient (Figure 1b). The surgeon then attaches the femoral head prosthesis comprising neocartilage (1) and trabecular metal (2) to the subchondral base (3), thereby forming an implant comprising cartilage and a subchondral base which replaces the patient's fractured femur head (Figure 1c).

Example 2

[0055] This example illustrates attachment of neocartilage to a subchondral base in vitro.

[0056] In this example, as shown in Figure 2, a subchondral base (5) comprising trabecular metal and shaped to replace a condyle (6) is rendered adherent for cartilage by application of a fibrin adhesive to the rounded surfaces of the trabecular metal. The rounded surfaces of the base is then contacted with neocartilage grown in vitro (7) (Figure 2a). The neocartilage (9) adheres to the adhesive layer (8), providing a layer of neocartilage following the contours of the surface of the base (9), thereby forming an implant which can replace a diseased or injured condyle of a patient (Figure 2b).

Example 3

[0057] This example illustrates use of a positioning structure to introduce an implant into a patient.

[0058] In this example, as shown in Figure 3, a subchondral base (11) comprising trabecular metal and having an internal screw thread is seeded with chondrocytes which are cultured to form neocartilage (10), thereby providing an implant (Figure 3a). A surgeon prepares a cylindrical-shape implant site which traverses the patient's cartilage and invades the bone in a condyle of the patient (13). The implant site has a depth and diameter corresponding to the implant. The surgeon then inserts a non-trabecular metal screw (14) into the site, leaving the screw partially exposed (Figure 3b). The surgeon then lightly presses the implant into the site, thereby engaging the exposed screw (14) with the internal screw thread of the implant. The surgeon presses on the implant until the neocartilage (1) is flush with the

patient's cartilage (Figure 3c). The neocartilage can then heal smoothly with the patient's own condyle cartilage (12), and the trabecular metal can attach to the bone.

Example 4

[0059] This example illustrates another configuration that uses a positioning structure to introduce an implant into a patient.

[0060] In this example, as shown in Figure 4, an intermediate positioning structure (16), which does not comprise trabecular metal, comprises a screw thread and a flat surface "platform" to which a fibrin adhesive is applied. Neocartilage (15) is applied to the platform, and cultured until it adheres (Figure 4a). A surgeon then prepares a cylindrical-shape implant site which traverses the cartilage and invades the bone (19) in a patient, and inserts a cylindrical-shape subchondral base comprising trabecular metal and an internal screw thread (17), as in Example 3 (Figure 4b). The surgeon then presses the intermediate positioning structure (16) into the subchondral base (17), until the neocartilage (15) is flush with the patient's cartilage (18). The neocartilage can then heal smoothly with the patient's own cartilage, and the trabecular metal can attach to the bone (Figure 4c).

Example 5

[0061] This example, as shown in Figure 5, illustrates attachment of cartilage to a subchondral base comprising trabecular metal.

[0062] In this example, Figure 5a shows attachment of cartilage (20) to trabecular metal (22) using sutures (21). Figure 5b shows attachment of cartilage (24) to trabecular metal (25) using staples, tacks or darts (23). Figure 5c shows attachment of cartilage (26) to trabecular metal (28) using an adhesive such as fibrin, collagen, or hydrogel (27). These configurations can be transplanted to a patient without in vitro culture, and are particularly useful for forming an implant either in vivo or in the operating room.

Example 6

[0063] This example illustrates seeding of chondrocytes onto trabecular metal of a subchondral base.

[0064] In this example, as shown in Figure 6, an implant is shown in which juvenile chondrocytes (29) allogeneic to a patient are seeded onto a surface of a subchondral base comprising trabecular metal (31). The surface for cell attachment comprises trabecular metal having a median pore diameter of from about 3 microns to about 20 microns. The surface for cell attachment is treated with sintered porous structured titanium to form a surface layer (30) prior to the seeding of cells.

[0065] In related configurations, the surface layer can also be formed with one or more of the following: a) trabecular metal fine pore phase; b) hyaluronic acid; c) collagen I; d) collagen II, e) fibrin (including autologous, allogeneic, xenogeneic, or synthetic); f) absorbable synthetic polymer such as PLA/PLG); synthetic or natural hydrogel; g) titanium screen or porous sheet. The configurations of this example, like those of Example 5, are also useful for forming an implant either in vivo or in the operating room.

Example 7

[0066] This example illustrates seeding of cells onto trabecular metal.

[0067] In this example, an implant as illustrated in Figure 6 is prepared as described in Example 6, except that seeding and culturing of cells is performed in vitro such that tissue grows and cells attach to pores of the trabecular metal or surface layer. This example illustrates seeding of cells onto trabecular metal for formation of cartilage in vitro.

Example 8

[0068] This example, as shown in Figure 7, illustrates a variety of useful implant shapes.

[0069] Figure 7a presents a cylindrical shape comprising a subchondral base comprising trabecular metal (33), and cartilage adherent on one surface (32).

[0070] Figure 7b presents an anatomical shape: the subchondral base comprising trabecular metal (35) comprises a contoured dual-hemispherical surface for cell attachment and two spikes (36) for insertion into bone (37), while the cartilage (34), which adopts the shape of the contoured surface, can replace the condyle of a distal femur.

[0071] Figure 7c presents a second anatomical shape: the subchondral base comprising trabecular metal comprises a contoured-hemispherical surface for cell attachment and a spike

(39) for insertion into bone (40), while the cartilage (38), which adopts the shape of the contoured surface, can replace a hemi-condyle.

Example 9

[0072] This example, as shown in Figure 8, shows additional anatomical shapes.

[0073] Figure 8a presents cartilage (41) attached to an anatomically shaped femoral head prosthesis, as presented in Example 1. The femoral head prosthesis attaches to a spike-shaped trabecular metal component (42) which, in turn, inserts into native bone (43). This shape can be used to repair a proximal femur.

[0074] Figure 8b presents an acetabular cup, which includes a cartilage component attached to a trabecular metal component, attached to native bone.

[0075] It is to be understood that particular formulations and processes of the present teachings are not limited to the descriptions of the specific embodiments presented, but rather the descriptions and examples should be viewed in terms of the claims that follow and their equivalents. While some of the examples and descriptions above may include some conclusions about the way the certain embodiments function, the inventors do not intend to be bound by those conclusions and functions, but put them forth only as possible explanations.

[0076] It is to be further understood that the specific embodiments of the present teachings as set forth are not intended as being exhaustive or limiting of the invention, and that many alternatives, modifications, and variations will be apparent to those of ordinary skill in the art in light of the foregoing examples and detailed description. Accordingly, the disclosed embodiments are intended to embrace all such alternatives, modifications, and variations that fall within the spirit and scope of the following claims.

[0077] All publications, patents, patent applications and other references cited in this application are herein incorporated by reference in their entirety as if each individual publication, patent, patent application or other reference were specifically and individually indicated to be incorporated by reference.

What is claimed is:

1. An implant comprising:

cartilage; and

a subchondral base comprising at least one trabecular metal component.

2. An implant in accordance with claim 1, wherein the at least one trabecular metal component comprises at least one metal selected from the group consisting of tantalum, niobium, stainless steel, a chromium-cobalt alloy and titanium.

3. An implant in accordance with claim 1, wherein the chromium-cobalt alloy is a chromium-cobalt-molybdenum alloy.

4. An implant in accordance with claim 1, wherein the at least one trabecular metal comprises a plurality of pores of median diameter from about 3 microns to about 800 microns.

5. An implant in accordance with claim 1, further comprising at least one porous surface layer comprising a plurality of pores of median diameter from about 3 microns to about 800 microns wherein the median diameter of the plurality of pores of the at least one porous surface layer is different from that of the plurality of pores of the subchondral base.

6. An implant in accordance with claim 5, wherein the at least one porous surface layer comprises a plurality of pores of median pore diameter of about 100 microns to about 800 microns.

7. An implant in accordance with claim 5, wherein the at least one porous surface layer comprises a plurality of pores of median pore diameter of about 3 microns to about 20 microns.

8. An implant in accordance with claim 1, wherein the subchondral base comprises at least two surfaces, wherein a first surface comprises trabecular metal comprising a plurality of pores having a median pore diameter of from about 100 microns to about 800 microns, and a second surface which is a cartilage-adherent surface.

9. An implant in accordance with claim 8, wherein the cartilage-adherent surface comprises a plurality of pores having a median diameter from about 3 microns to about 20 microns.

10. An implant in accordance with claim 8, wherein the cartilage-adherent surface comprises a cartilage adhesive.

11. An implant in accordance with claim 10, wherein the cartilage adhesive comprises a biological macromolecule selected from the group consisting of hyaluronic acid, collagen type I, collagen type II, fibrin and a combination thereof.

12. An implant in accordance with claim 11, wherein the fibrin is selected from the group consisting of fibrin autologous to a mammalian recipient of the implant, fibrin allogeneic to a mammalian recipient of the implant, fibrin xenogeneic to a mammalian recipient of the implant, synthetic fibrin, and a combination thereof.

13. An implant in accordance with claim 8, wherein the cartilage-adherent surface is a chondrocyte-adhesive surface.

14. An implant in accordance with claim 9, wherein the cartilage-adherent surface further comprises a cartilage adhesive.

15. An implant in accordance with claim 14, wherein the cartilage adhesive comprises a biological macromolecule selected from the group consisting of hyaluronic acid, collagen type I, collagen type II, fibrin and a combination thereof.

16. An implant in accordance with claim 15, wherein the fibrin is selected from the group consisting of fibrin autologous to a mammalian recipient of the cartilage, fibrin allogeneic to a mammalian recipient of the cartilage, fibrin xenogeneic to a mammalian recipient of the cartilage, synthetic fibrin, and a combination thereof.

17. An implant in accordance with claim 1, wherein the subchondral base further comprises a biocompatible porous metal sheet.

18. An implant in accordance with claim 17, wherein the biocompatible porous metal sheet is a porous titanium sheet.

19. An implant in accordance with claim 1, wherein the subchondral base further comprises a biocompatible non-porous metal sheet.

20. An implant in accordance with claim 1, wherein the at least one trabecular metal comprises porous tantalum.

21. An implant in accordance with claim 1, wherein the at least one trabecular metal comprises sintered porous cancellous-structured titanium.

22. An implant in accordance with claim 8, wherein the cartilage-adherent surface comprises an absorbable polymer.

23. An implant in accordance with claim 22, wherein the absorbable polymer is polylactic/polyglycolic acid (PLA/PGA).

24. An implant in accordance with claim 8, wherein the cartilage-adherent surface comprises a chondroconductive material selected from the group consisting of hydroxyapatite, hydroxyapatite-tricalcium phosphate, and a combination thereof.

25. An implant in accordance with claim 1, wherein the cartilage is juvenile cartilage.

26. An implant in accordance with claim 1, wherein the cartilage is minced cartilage.

27. An implant in accordance with claim 1, wherein the cartilage is neocartilage.

28. An implant in accordance with claim 27, wherein the neocartilage is minced neocartilage.

29. An implant in accordance with claim 1, wherein the cartilage is devitalized cartilage.

30. An implant in accordance with claim 1, wherein the cartilage is allogeneic to a mammalian recipient of the implant.

31. An implant in accordance with claim 1, wherein the cartilage is autologous or xenogeneic to a mammalian recipient of the implant.

32. An implant in accordance with claim 1, wherein the cartilage is selected from the group consisting of articular cartilage, hyaline cartilage, auricular cartilage, cartilage comprising genetically modified chondrocytes, cartilage comprising chondrocytes differentiated from mesenchymal stem cells, and a mixture thereof.

33. An implant in accordance with claim 1, wherein the cartilage comprises chondrocytes grown in vitro in contact with the at least one trabecular metal.

34. An implant in accordance with claim 1, wherein the cartilage and the subchondral base are attached.

35. An implant in accordance with claim 34, further comprising at least one suture which attaches the cartilage to the subchondral base.

36. An implant in accordance with claim 34, further comprising at least one biocompatible adhesive which attaches the cartilage to the subchondral base, wherein the at least one biocompatible adhesive comprises a macromolecule selected from the group consisting of a fibrin, a collagen, and a combination thereof.

37. An implant in accordance with claim 34, further comprising at least one absorbable fastener which attaches the cartilage to the subchondral base.

38. An implant in accordance with claim 36, wherein the at least one absorbable fastener is selected from the group consisting of a staple, a dart, a pin and a tack.

39. An implant in accordance with claim 34, further comprising at least one laser weld.

40. An implant in accordance with claim 1, wherein the implant is substantially cylindrical, substantially a pyramidal wedge, or substantially frustoconical in shape.

41. An implant in accordance with claim 1, wherein the implant comprises a substantially anatomical shape selected from the group consisting of a human condyle, a human hemi-condyle, a human acetabular cup and a human femoral head.

42. An implant in accordance with claim 1, wherein the at least one trabecular metal component comprises a chondrocyte-retaining geometry selected from the group consisting of plurality of barbs, a plurality of ridges and a plurality of hooks.

43. An implant in accordance with claim 1, wherein the implant is an implant for administering to a mammal in need of treatment of joint disease, defect or injury.

44. An implant in accordance with claim 43, wherein the mammal is a human patient.

45. An implant in accordance with claim 1, wherein the cartilage comprises juvenile chondrocytes.

46. An implant for administering to a patient in need of treatment of joint disease, defect or injury, the implant comprising:

chondrocytes; and

a subchondral base comprising at least one trabecular metal.

47. A method of forming an implant comprising cartilage and a subchondral base, the method comprising:

growing cartilage comprising juvenile chondrocytes in vitro; and

contacting the juvenile chondrocytes with a subchondral base comprising trabecular metal.

48. A method in accordance with claim 47, further comprising applying a cartilage adhesive to the subchondral base prior to the contacting the juvenile chondrocytes with the subchondral base.

49. A method in accordance with claim 47, further comprising attaching the cartilage to the subchondral base.

50. A method in accordance with claim 49, wherein the attaching the cartilage to the subchondral base comprises:

applying to the subchondral base or the cartilage at least one biocompatible adhesive selected from the group consisting of a fibrin, a collagen and a combination thereof; and

applying the cartilage to the subchondral base.

51. A method of treating joint disease, defect or injury in a patient in need thereof, the method comprising introducing into the patient an implant, the implant comprising cartilage and a subchondral base comprising trabecular metal.

52. A method of treating joint disease, defect or injury in a patient in need thereof, the method comprising: introducing into the patient a subchondral base comprising trabecular metal, wherein the subchondral base is configured to receive cartilage; andapplying cartilage to the subchondral base after introducing the subchondral base into the patient.

53. A method in accordance with claim 52, further comprising introducing into the patient a positioning structure.

54. A method of treating joint disease, defect or injury in a patient in need thereof, the method comprising:

introducing into the patient a subchondral base comprising trabecular metal, wherein the subchondral base is configured to receive chondrocytes; and

applying chondrocytes to the subchondral base after introducing the subchondral base into the patient.

55. A method of forming an implant, the method comprising attaching cartilage tissue to a surface of a trabecular metal component.

56. A method in accordance with claim 55, wherein the attaching comprises applying a cartilage adhesive to the surface of the trabecular metal component prior to contacting the cartilage tissue to the surface of the trabecular metal component.

57. A method of forming an implant, the method comprising growing chondrocytes in the presence of a trabecular metal component such that the chondrocytes adhere to a surface of the component.

58. A method of claim 57, wherein growing chondrocytes comprises forming cartilage.

59. A method of forming an implant, the method comprising coupling cartilage tissue to a surface of a trabecular metal component of an implant.

60. An implant comprising:

cartilage; and

a subchondral base comprising at least one trabecular metal.

61. A kit comprising:

chondrocytes or cartilage; and

a component of an implant comprising trabecular metal.

62. A kit in accordance with claim 61, wherein the chondrocytes or cartilage are packaged separately from the component comprising trabecular metal.

63. A kit in accordance with claim 61, wherein the chondrocytes or cartilage are attached to the component comprising trabecular metal.

64. A kit in accordance with claim 61, further comprising instructions.

65. A kit in accordance with claim 61, further comprising cell culture medium.

66. A kit in accordance with claim 61, further comprising at least one fastener selected from the group consisting of suturing thread, a staple, a dart, and a tack.

67. A kit in accordance with claim 61, further comprising a positioning device.

68. Use of an implant comprising a) cartilage or chondrocytes and b) trabecular metal in the manufacture of a medicament for treatment of joint disease, repair, or injury.

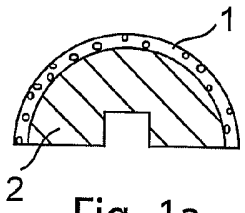



Fig. 1a

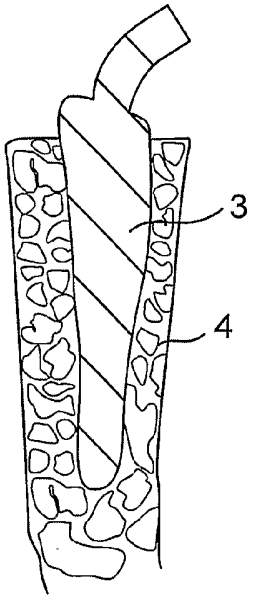



Fig. 1b

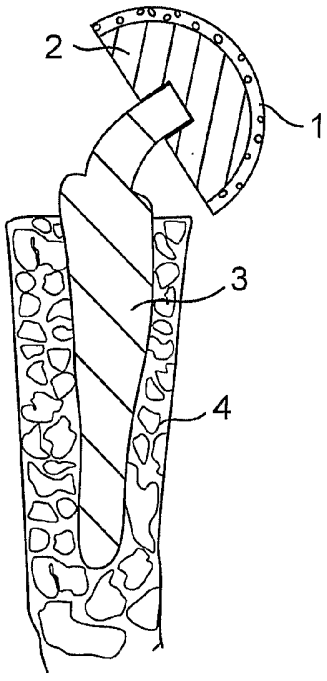



Fig. 1c

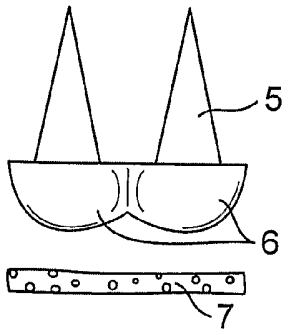



Fig. 2a

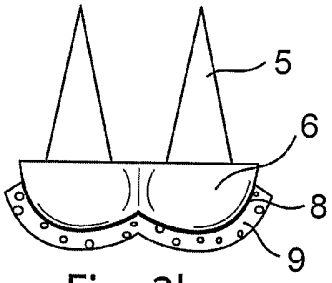



Fig. 2b

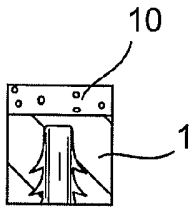



Fig. 3a

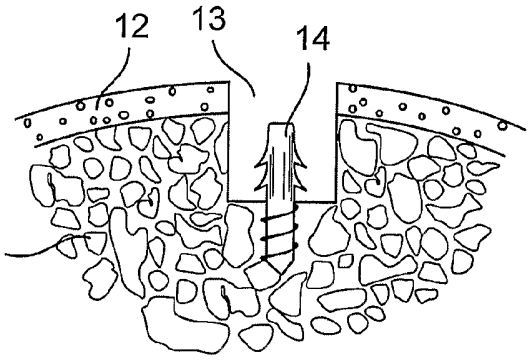



Fig. 3b

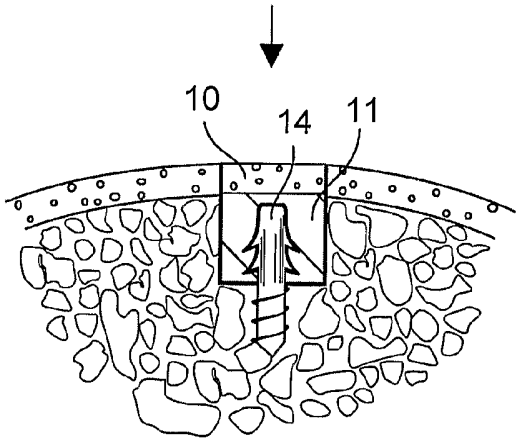



Fig. 3c

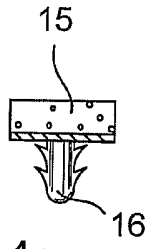



Fig. 4a

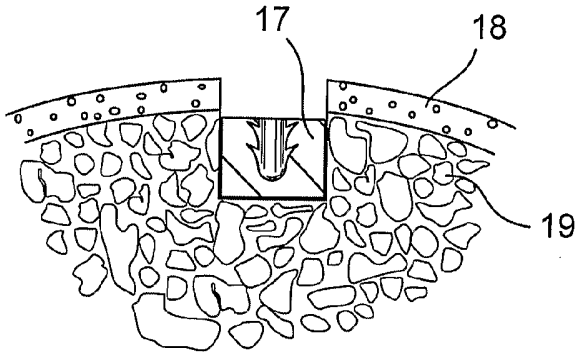



Fig. 4b

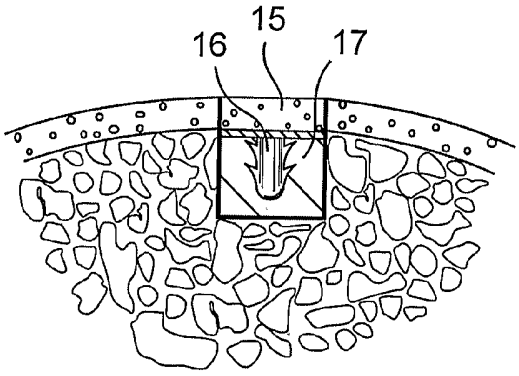



Fig. 4c

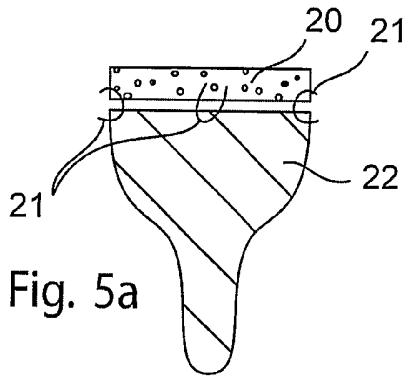



Fig. 5a

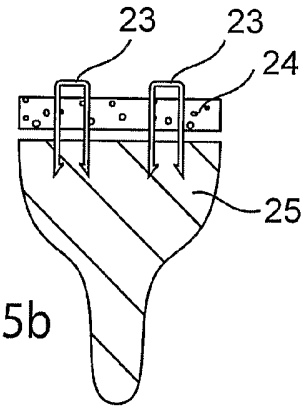



Fig. 5b

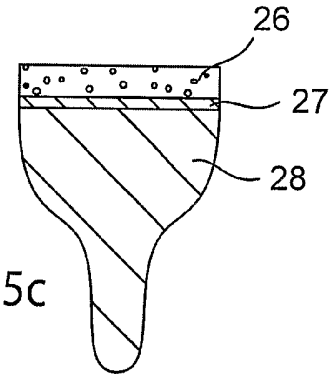



Fig. 5c

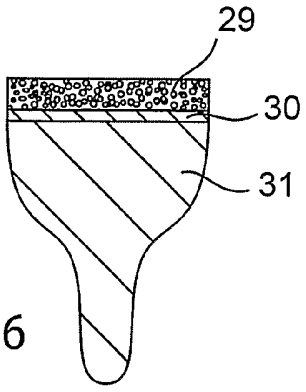



Fig. 6

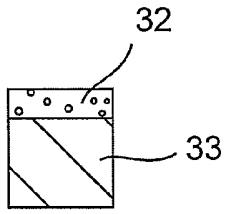



Fig. 7a

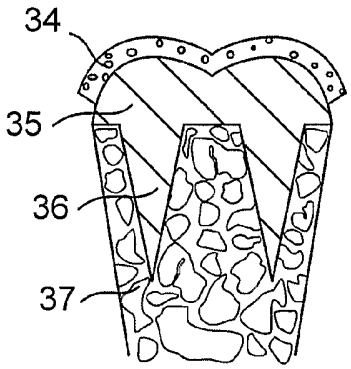



Fig. 7b

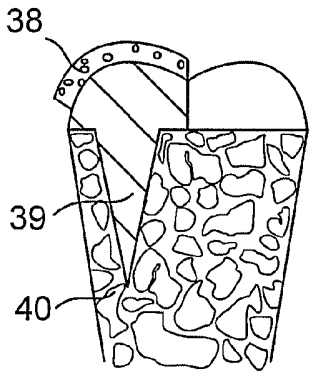



Fig. 7c

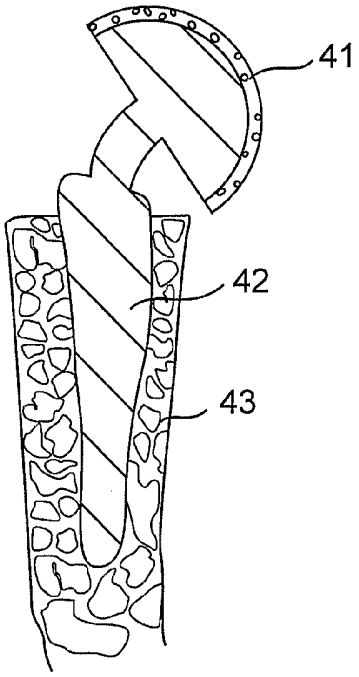



Fig. 8a

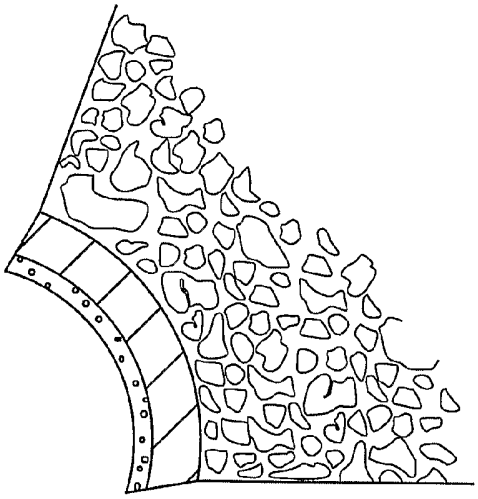


Fig. 8b