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(71) Applicant(s)

Catherine Cadorel

(72) Inventor(s)

Cougoulic, Jean-Pierre

(74) Agent/Attorney

Watermark Patent and Trade Marks Attorneys, Level 2 302 Burwood Road, Hawthorn, VIC, 3122

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(71) Déposant *(pour tous les États désignés sauf US)* : **CADOREL, Catherine** [FR/FR]; 90, route de la Ville Joie, F-44500 la Baule (FR).

(72) Inventeur; et
(75) Inventeur/Déposant *(pour US seulement)* : **COUGOULIC, Jean-Pierre** [FR/FR]; 7 bis, avenue du 18 Juin 1940, F-44380 Pornichet (FR).

(74) Mandataires : **MICHELET, Alain** etc.; Cabinet Harle et Phelip, 7, rue de Madrid, F-75008 Paris (FR).

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(54) **Title:** MEDICAL OR VETERINARY MATERIAL, METHOD FOR THE PRODUCTION AND USE THEREOF

(54) **Titre :** MATERIAU A USAGE MEDICAL OU VETERINAIRE, SON PROCEDE D'OBTENTION ET SES APPLICATIONS

(57) **Abstract:** Said material is embodied in the form of a moulded part consisting of a biocompatible binder containing one or several compounds providing calcium and phosphorous, characterised in that the surface thereof is etched in order to ensure the surface placement and the surface access of elements added to the binder, i.e. calcium and phosphorous. The material can be used advantageously in order to produce endo-bone implants or bone prostheses. .

(57) **Abrégé :** Ce matériau se présente sous la forme d'une pièce moulée, constituée d'un liant biocompatible contenant un ou plusieurs composés réalisant un apport de calcium et de phosphore, caractérisé par le fait qu'il a subi une opération de décapage surfacique destiné à assurer la mise en surface et donc l'accès en surface des éléments ajoutés au liant, notamment du calcium et du phosphore. Ce matériau peut avantageusement être utilisé pour la réalisation d'implants endo-osseux ou de prothèses osseuses.

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MEDICAL OR VETERINARY MATERIAL, METHOD FOR THE PRODUCTION AND USE THEREOF

The present invention refers to an original material in the form of an implantable product and which may be used in the medical or veterinary field, in particular but not exclusively for endo-bone implants, in particular dental implants, or for bone prostheses. The invention also refers to the method of production of such implantable product, as well as the applications thereof.

Numerous types of materials, metal or plastic materials are used in the medical or veterinary field for replacing biological structures (bone in particular) or for fastening functional organs (dental implants or others...).

The material is selected in relation to its intrinsic structural characteristics and also in relation to its biocompatibility in terms of tolerance or, even better, in terms of biological acceptance.

The document FR-A-2 72 694 describes a moulded material for endo-bone implants or of bone prostheses, made of thermoplastic polymer (in particular poly(etheretherketon), also called PEEK) comprising calcium hydroxyapatite, tricalcic phosphate, orthophosphoric acid and a TiO_2-type zeolite.

In spite of the encouraging results obtained with this type of material, it appears that the results in terms of biological integration are not quite satisfactory.

The present invention offers a new material in the form of an implantable product, derived from that described in the document aforementioned FR-A-2 72 694, which combines good overall mechanical qualities and very good biocompatibility in terms of biological acceptance, enabling thereby efficient use in the medical field as well as in the veterinary field.

The implantable product is in the form of a moulded part made of a biocompatible binder containing one or several compounds for adding calcium and phosphorus, which moulded part has been subjected to surface pickling operation.

Such pickling ensures surface application and hence surface access of the elements added to the binder, in particular calcium and phosphorus; this enables to create or at least to promote the creation of ionic links between such added elements and the surrounding chemical elements, mineral or organic elements, after biological implantation of the implantable product. And in case of resorbable added elements present, once such elements have disappeared, the tissues, the biological cells or the surrounding chemical elements may find a place for integration in the material.

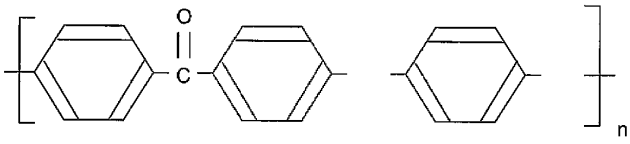
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This particularity enables an improvement in the adherence and the cell colonisation to ensure good biological graft-type acceptance and good biocompatibility of the implant.

The biocompatible binder is selected in relation to its physical characteristics after shaping in particular by an injection-moulding operation. By way of example, a thermoplastic polymer such as poly(etheretherketon), ketone polyether, amide block polyether, polytétrafluoréthylène or still polyimide may be used; a natural polymer, in particular such as cellulose, may also be utilised. Such polymer can be resorbable or not.

Because of its high Young's modulus and its interesting structural characteristics, close to those of the bone, poly(etheretherketon) (PEEK) is used preferably. PEEK is a semi-crystalline polymer made of an aromatic linear chain based on the repetition of the following units:



The characteristics of this polymer are expanded on in the commercial leaflet published in 1992 by ICI MATERIALS: « Victrex PEEK, the high temperature engineering thermoplastic-properties and processing ».

The additions of calcium and phosphorus are composed advantageously of calcium phosphates derived form example from tricalcic phosphate (Ca_3 $(PO_4)_2$), dicalcic or monetite phosphate (Ca H PO_4), with stoichiometric formulation ((Ca_5 $(PO_4)_3$ OH) or (Ca_{10} $(PO_4)_6H20$)), with stoichiometric formulation or not, or of products containing said elements.

The presence of calcium phosphates enables the implantable product to approximate the natural composition of the bone in order to enhance the biocompatibility thereof. Products containing calcium phosphates, which are at least partially resorbable, are used preferably.

In particular, calcium hydroxyapatite is a component that can be found in the bone. It can be utilized advantageously in its non-stoichiometric form, since it is then slightly resorbable, which is interesting for cellular integration.

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Dicalcic or tricalcic phosphate is advantageously cheap and one of the basic biological components for the formation of calcium hydroxyapatite; it is also resorbable and has also a healing function.

These various additions of calcium phosphates may also be used as mixtures.

Besides the addition of calcium phosphates, the moulded material according to the invention may contain orthophosphoric acid (H_3 (PO_4)). Natural orthophosphoric acid is prescribed as a calcium fixative and as an acidifier; it is also a fundamental component of the nucleotides which as the basic units of nucleic acids, which partake of the constitution of the nucleus of living cells.

Moreover, the implantable product according to the invention is advantageously laden with one or several compounds enabling to create or promote the electrostatic links with the surrounding medium. This(these) charge(s) may be selected among zeolites and/or certain oxides: using ceramics such as titanium dioxide (TiO_2), zirconium dioxide (ZrO_2), aluminium oxide (Al_2O_3) or silicium dioxide (SiO_2) may be contemplated.

The charges in question are electrostatic compounds which allow ionic bonding function; they have moreover high molar mass and they contribute to improve the radio-opacity of the material.

The implantable product according to the invention is shaped by moulding, injection or extrusion moulding, of a homogeneous mixture of constituents. The material and the moulding conditions are suited to this mixture, and in particular the nature of the binder used.

To keep an implantable product with sufficient handling and resistance, the polymer binder represents at least 65 %, and preferably 65 % to 90 %, in weight of the finished material.

On the other hand, to add sufficient quantity of chemical elements intended to promote the biological integration, the complementary components (tricalcic phosphate and/or dicalcic phosphate and/or calcium hydroxyapatite, possibly associated with at least one compound of zeolite or oxide type for example, intended to improve electrostaticity and radio-opacity, and with orthophosphoric acid) represent between 10 and 35 % in weight of the finished material.

A good compromise, in particular in terms of mechanical characteristics corresponds substantially to 80% in weight of polymer binder and 20% in weight of complementary component(s).

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The invention, the subject of this application, is directed to a method for producing an implantable product wherein the method comprises in order of performance the steps consisting of:

- injection moulding an implantable product with a material consisting in 65% to 90% in weight of a polymer biocompatible binder and 10% to 35% in weight of calcium phosphate; and
- surface pickling and decontamination of the moulded implantable product wherein said surface pickling and decontamination operations comprise passing the moulded implantable product in successive baths subjected to ultrasound in the following order:
  - a hydrochloric or sulphuric acid bath,
  - an acetone bath,
  - a hydrogen peroxide bath,
  - a sodium hydrochlorite bath, and
  - a disinfectant product(s),

  each of said baths being separated by operations comprising water rinsing or passing in water baths subjected to ultrasound; and
- a subsequent sterilization operation by autoclave;

wherein said surface treatment is such as the surface of said moulded implantable product is provided with emerging crystallized calcium phosphate that is resorbable after implantation.

According to one aspect of the invention, there is provided an implantable product ready for implantation into a living bone tissue, made of 65 to 90% by weight of a biocompatible thermoplastic polymer binder and of 10 to 35% by weight of calcium phosphate, wherein said calcium phosphate emerges in the form of crystals from the surface of the implantable product.

The implantable product is preferably suited for medicinal or veterinary usage, in particular for endo-bone implants, in particular dental implants or for bone prostheses.

In general terms the corresponding method comprises: - mixing homogeneously a mouldable binder biocompatible with one or several components for adding calcium and phosphorus, - subjecting the mixture thus obtained to a moulding operation, - performing one or several surface pickling and decontamination operations of the moulded part, - conditioning aseptically said decontaminated part.

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The surface pickling operation is advantageously carried out by dint of at least one bath in a solution, in particular a pickling product, subjected to ultrasounds.

Preferably, the surface pickling and decontamination operations consist in passing the moulded part in successive baths of hydrochloric or sulphuric acid, acetone, hydrogen peroxide, sodium hypochloride and disinfectant product(s), submitted to ultrasounds, separated by operations consisting in water rinsing or passing in water baths submitted to ultrasounds.

Examples

Basic mixtures are prepared out of poly(etheretherketon) (PEEK), tricalcic phosphate ($Ca_3 (PO_4)_2$), and titanium dioxide (TiO_2).

The PEEK is in the form of a powder or of granules (size: approx. 100 microns), available from Victrex Europa GmbH, Hauptstr. 11 D-65719 HOFHEIM - Germany.

Tricalcic phosphate is available in the form of a powder (grain size close to 200 microns); it is for instance marketed by Coopération Pharmaceutique Française, 77020 MELUN - France.

Titanium oxide is also available in the form of a powder distributed by Coopération Pharmaceutique Française, 77020 MELUN - France.

a) Proportions

Some possible examples of compositions are specified below:

Mixture 1 (10% charges)		Mixture 2 (20 % charges)	
- PEEK	: 90 % in weight	- PEEK	: 80 % in weight
- $Ca_3(PO_4)_2$	: 5 % in weight	- $Ca_3(PO_4)_2$	: 10 % in weight
- TiO_2	: 5 % in weight	- TiO_2	: 10 % in weight

Mixture 3 (30 % charges)		Mixture 4	
- PEEK	: 70 % in weight	- PEEK	: 65 % in weight
- $Ca_3(PO_4)_2$	: 15 % in weight	- $Ca_3(PO_4)_2$	: 17.5 % in weight
- TiO_2	: 15 % in weight	- TiO_2	: 17.5 % in weight

b) Mingling

The constituents of each mixture are placed in a turbine mixer until perfect homogenising.

c) Drying

Each homogeneous mixture obtained is dried in an air circulation stove for 3 hours at 150°C.

d) Moulding

The moulding operation is performed on a KRAUSS-MAFFEL-type injection press. Model 90-340-32, KRAUSS MAFFEI FRANCE, 92632 GENNEVILLIERS - FRANCE.

The preparation conditions of the material and the moulding conditions of the mixture correspond to the commercial leaflet « ICI MATERIALS » specified above.

PEEK being a semi-crystalline thermoplastic, it is necessary to heat the mould to a temperature at least greater than that of its vitreous transition (140°C). Failing which the surface quality of the moulded parts would be affected. Indeed, the surface web would be in amorphous phase and the core in crystalline phase; if the mould were too cold, the parts might even have totally amorphous character and the mechanical characteristics would drop considerably.

Thermoregulation of the mould is ensured by an oil re-heater enabling to maintain it at a temperature of the order of 160°C. Insulation means limit thermal dispersions and preserve the peripheral organs of the injection press. Such means may be in the form of insulating plates formed of a fibre glass complex.

For series injections, a vibrator will be advantageously fixed to the hopper to promote the flow of the mixture.

Generally speaking, moulding is conducted at a temperature of the order of 340 to 400°C and at an injection pressure close to 70 to 140 MPa.

The mould may be shaped in relation to the part to be obtained, for example for realising bone prosthesis, in particular for orthopaedic applications. A block of matter can also be obtained that will then be cut or machined to the desired shape, for bone filling or an implant, of dental type for example.

e) Surface pickling - decontamination

After obtaining the moulded material, the former is subjected to surface pickling and decontamination operations, before aseptic conditioning.

Such operations are conducted advantageously in a first step by passing the moulded material in different product baths subjected to ultrasounds; each product used may play the part of surface pickling agent or disinfectant, or both.

Obviously, the product(s) ensuring the surface pickling operation are suited, in combination with ultrasounds, to expose in surface in particular phosphorus and calcium (in the form of calcium phosphate), and titanium dioxide. Surface accessibility of the calcium phosphate promotes exchanges with the environment and electrostatic bonding of certain chemical elements present in the biological environment of the material after implantation, said exchanges and/or electrostatic bonding induce cellular penetration in the implanted material. Also, the presence of titanium dioxide in surface may induce said exchanges and the presence of electrostatic links.

Moreover, calcium phosphate being at least partially resorbable, its disappearance after implantation of the material enables to create cavities or a cavity network, promoting cellular penetration in the surrounding tissues.

The products used for these surface pickling and decontamination operations may be hydrochloric acid, (HCl, for example 30 %) or sulphuric acid (H_2SO_4, for example 30 %), acetone (C_3H_6O), hydrogen peroxide (H_2O_2, at 110 vol. or 30 % for example), and/or sodium hypochloride (NaClo) used preferably in combination. Advantageously, complementary product baths are used with purely disinfecting function, such as Gigasept (registered trademark) or Lysetol (registered trademark).

The corresponding protocol for implementing these pickling/decontamination operations may consists in placing the implant in the different following successive baths subjected to ultrasounds:

- HCl 30 % : 20 mn
- H_2O : 10 mn (or rinsing)
- acetone: 20 mn
- H_2O : 10 mn (or rinsing)
- H_2O_2 30 % : 20 mn
- NaclO : 20 mn
- H_2O : 10 mn (or rinsing)
- Gigasept 12 % : 60 mn
- H_2O Ppi: 20 mn (or rinsing)

The implant is inserted in a sterilisation sheath for passing in an autoclave; it is then subjected to a sterilisation cycle at a temperature of the order of 135°C for 10 minutes, under a pressure of the order of 2150 mbars. This sterilisation operation by autoclave contributes to the surface pickling function; it may be associated with a treatment by ethylene oxide or by gamma rays.

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f) Results

An electronic scanning microscope analysis shows that the pickling/decontamination and sterilisation operations promote the apparition of calcium phosphates in surface. These calcium phosphates emerge through micropores and crystallise.

After implantation, surface analysis shows the presence of holes and chaps at the surface of the material, and also the presence of carbon, oxygen and nitrogen, whereas little calcium and phosphorus can be found relative to the initial integrated concentrations.

This tends to show partial disappearance of the calcium phosphate particles in surface, and the colonisation of the holes and chaps by surrounding biological materials, sign of a graft-type biological acceptance.

Clinical analysis from inserted implants shows that the material in question develops at the contact thereof a cortical bone further to the physical and atomic characteristics of the material.

It is here a true graft principle; these results demonstrate the clinical reality of an integration of the material to the surrounding tissue.

"Comprises/comprising" when used in this specification is taken to specify the presence of stated features, integers, steps or components but does not preclude the presence or addition of one or more other features, integers, steps, components or groups thereof.

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THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A method for producing an implantable product for implantation into a living bone tissue, wherein said method comprises in order of performance the steps consisting of:

- injection moulding an implantable product with a material consisting in 65% to 90% in weight of a polymer biocompatible binder and 10% to 35% in weight of calcium phosphate; and
- surface pickling and decontamination of the moulded implantable product wherein said surface pickling and decontamination operations comprise passing the moulded implantable product in successive baths subjected to ultrasound in the following order:
  - a hydrochloric or sulphuric acid bath,
  - an acetone bath,
  - a hydrogen peroxide bath,
  - a sodium hydrochlorite bath, and
  - a disinfectant product(s),

  each of said baths being separated by operations comprising water rinsing or passing in water baths subjected to ultrasound; and
- a subsequent sterilization operation by autoclave;

wherein said surface treatment is such as the surface of said moulded implantable product is provided with emerging crystallized calcium phosphate that is resorbable after implantation.

2. An implantable product for implantation into a living bone tissue, produced by the method according to claim 1.

3. An application of the implantable product according to claim 2 for endo-bone implants.

4. The application according to claim 3 for dental implants.

5. An application of the implantable product according to claim 2 for bone prostheses.

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6. An implantable product for implantation into a living bone tissue, wherein the implantable product is substantially as hereinbefore described with reference to the examples.

CATHERINE CADOREL

WATERMARK PATENT AND TRADE MARKS ATTORNEYS

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