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(54) **Title**: OSSEOINTEGRATIVE SURGICAL IMPLANT

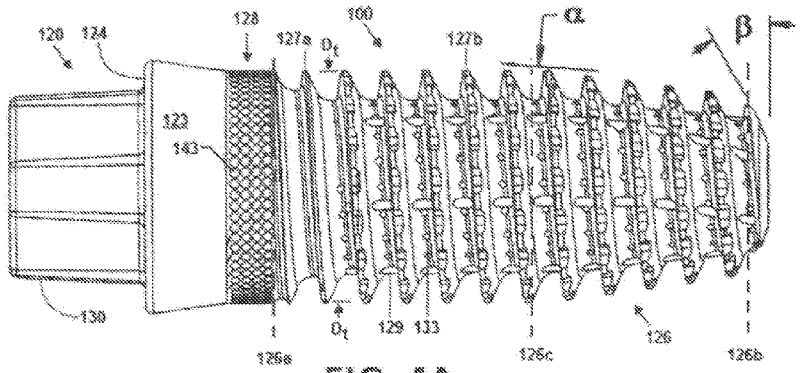

FIG. 4A

(57) **Abstract**: Embodiments of the present invention provide an osseointegrative implant and related tools, components and fabrication techniques for surgical bone fixation and dental restoration purposes. In one embodiment an all-ceramic single-stage threaded or press-fit implant is provided having finely detailed surface features formed by ceramic injection molding and/or spark plasma sintering of a powder compact or green body comprising finely powdered zirconia. In another embodiment a two-stage threaded implant is provided having an exterior shell or body formed substantially entirely of ceramic and/or CNT-reinforced ceramic composite material. The implant may include one or more frictionally anisotropic bone-engaging surfaces. In another embodiment a densely sintered ceramic implant is provided wherein, prior to sintering, the porous debound green body is exposed to ions and/or particles of silver, gold, titanium, zirconia, YSZ, α-tricalcium phosphate, hydroxyapatite, carbon, carbon nanotubes, and/or other particles which remain lodged in the implant surface after sintering. Optionally, at least the supragingival portions of an all-ceramic implant are configured to have high translucence in the visible light range. Optionally, at least the bone-engaging portions of an all-ceramic implant are coated with a fused layer of titanium oxide.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US15/28363

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - A61C 13/08, 13/083 (2015.01)
CPC - A61L 27/00
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC(8): A61C 13/08, 13/083 (2015.01)
CPC: A61L 27/00; USPC: 264/19, 109, 667

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
PatSeer (US, EP, WO, JP, DE, GB, CN, FR, KR, ES, AU, IN, CA, Other Countries (INPADOC), RU, AT, CH, TH, BR, PH); Google Patents; Google; Google Scholar; EBSCO; PubMed/Medline; Search terms used: dental, orthodont*, teeth, tooth, implant, powder*, *zirconia, heat*, binder, die, mold, mould, "green body", thread*, sinter*, coalesc*, compress*, pressur*, current, MPa, density

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	WO 2013/190043 A2 (IVOCLAR VIVADENT AG) December 27, 2013; page 7, lines 25-29; page 17, lines 18-19, 23-26; page 18, lines 27-28; page 20 lines 15-20; claims 1, 7, 19	7, 13 ----- 8-9, 11
Y	US 2012/0301849 A1 WANG, MW et al.) 29 November 2012; figures 3, 4, 10; paragraphs [0028], [0035]	8
Y	US 2005/0012231 A1 (OLSSON, K et al.) January 20, 2005; figure 1; paragraphs [0001], [0012], [0019]-[0020], [0023]-[0025], [0028]-[0030], [0122]-[0129], [0141], [0162]-[0165], [0168], [0215]; claims 1-25	9, 11
A	US 2004/0121286 A1 (ARAVENA, IM et al.) June 24, 2004; figure 1; paragraphs [0025], [0031],	1-6, 10, 12, 14
A	US 5192325 A (KIJIMA, N et al.) March 9, 1993; column 1, lines 63-68; column 6, lines 25-62	1-6, 10, 12, 14
A	US 2013/0177468 A1 (SEIKO EPSON CORPORATION) July 11, 2013; abstract; figures 1A-C, 2A, 5; paragraphs [0051], [0078], [0081], [0085], [0106], [0304]-[0308]	1-6, 10, 12, 14
A	US 2003/0059742 A1 (WEBSTER, TJ et al.) March 27, 2003; paragraphs [0029], [0056]; claim 20	7-14
A	US 5342201 A (ODEN, A) August 30, 1994; abstract; figure 3a; column 3, lines 42-43; column 4, lines 23-25; column 5, lines 49-52	14

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
17 September 2015 (17.09.2015)	13 OCT 2015
Name and mailing address of the ISA/ Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	Authorized officer Shane Thomas PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US15/28363

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

Group I: Claims 1-6; Group II: Claims 7-14; Group III: Claims 15-28; Group IV: Claims 29-33; Group V: Claims 34-37; Group VI: Claims 38-47; Group VII: Claims 48(A), 48(B)

This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1.

-***-Continued on Next Supplemental Page-***-

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. ☒ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
1-14

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☒ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US15/28363

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 6,592,805 B1 (Wang, J et al.) 15 July 2003; column 4, lines 16-17; column 6, lines 34-39	12
A	US 5,063,003 A (GONZALEZ-OLIVER, C) 05 November 1991; column 14, lines 40-44	12
A	US 5,110,513 A (PUVILLAND. G) 05 May 1992; column 5, lines 1-2	14

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/US15/28363

-***-Continued from Box III - Observations where unity of invention is lacking -***-

Group I: Claims 1-6 are directed toward a ceramic implant produced by: injecting a powdered ceramic feedstock into a mold cavity comprising at least one female thread to form a green body, said green body having at least one mating male thread corresponding to said at least one female thread.

Group II: Claims 7-14 are directed toward a ceramic implant produced by: compacting a powdered ceramic material into a die cavity, said powder compact having a density greater than about 40% of maximum theoretical density.

Group III: Claims 15-28 are directed toward a ceramic implant produced by: injecting a powdered ceramic feedstock into a mold cavity to form a a debound green body having a fluid-permeable interconnected porous structure; and modifying a portion of the outer surface of said debound green body by introducing nanoparticles such that some of said nanoparticles enter and remain lodged in said fluid-permeable interconnected porous structure.

Group IV: Claims 29-33 are directed toward a ceramic implant comprising a mixture of powdered zirconia and at least 0.5 wt% carbon nanotubes (CNT).

Group V: Claims 34-37 are directed toward a ceramic implant having multiple discrete surface features arranged in a pattern having a surface packing density greater than 0. 75 and wherein each discrete surface feature has a depth or height smaller than 0.15 mm.

Group VI: Claims 38-47 are directed toward an anchoring body for an implant comprising an exterior shell or body formed substantially entirely of ceramic and/or CNT reinforced ceramic composite material.

Group VII: Claims 48(A) and 48(B) are directed toward a torque driver comprising an input drive shaft, an output drive shaft, and a torque-limiting transfer coupling connecting said input drive shaft and said output drive shaft.

The inventions listed as Groups I-VII do not relate to a single general inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons.

The special technical features of Group I include mold cavity comprising at least one female thread; causing or allowing said injected feedstock to cool in said mold cavity such that it forms a substantially solid green body having at least one mating male thread corresponding to said at least one female thread, which are not present in Groups II-VII. The special technical features of Group II include forming a powder compact having a density greater than about 40% of maximum theoretical density, and sintering while regulating temperature and pressure to compact powder to about 95% of theoretical density, which are not present in Groups I and III-VII. The special technical features of Group III include producing a debound green body having a fluid-permeable interconnected porous structure; modifying at least a portion of the outer surface of said debound green body by introducing nanoparticles of material sufficiently small in size such that at least some of the nanoparticles enter and remain lodged in the fluid-permeable interconnected porous structure, which are not present in Groups I, II and IV-VII. The special technical features of Group IV include a sintered body formed by densely sintering a green body or powder compact comprising a mixture of powdered zirconia and at least 0.5 wt% carbon nanotubes (CNT), which are not present in Groups I-III and V-VII. The special technical features of Group V include a ceramic implant having multiple discrete surface features arranged in a pattern having a surface packing density greater than 0.75, and wherein each discrete surface feature has a depth or height smaller than 0.15 mm, which are not present in Groups I-IV, VI and VII. The special technical features of Group VI include an anchoring body for an implant comprising an exterior shell or body formed substantially entirely of ceramic and/or CNT reinforced ceramic composite material, which are not present in Groups I-V and VII. The special technical features of Group VII include a torque driver comprising an input drive shaft, an output drive shaft, and a torque-limiting transfer coupling connecting said input drive shaft and said output drive shaft, which are not present in Groups I-VI.

The shared technical features of Groups I-III include injecting a powdered ceramic material into a mold cavity, and sintering the green body. The shared technical features of Groups I-V include a ceramic implant. The shared technical features of Groups I and III include forming a green body from a feedstock comprising a colloidal mixture of a powdered ceramic material; and removing and debinding the green body. The shared technical features of Groups II and V include the ceramic implant having exterior surface features. The shared technical features of Groups III and IV include the ceramic implant comprising nanoparticles.

However, these shared features are previously disclosed by US 2013/0236854 A1 to McEntire, et al. (hereinafter 'McEntire') and US 2009/0321971 A1 to Brodkin, et al. (hereinafter 'Brodkin').

McEntire discloses a ceramic implant (dental implants include a bone anchor comprising silicon nitride ceramic; paragraph [0015]), powders of ceramic material (powders of silicon nitride may be used to form the ceramic implants; paragraph [0011]) into a green body in a mold cavity (forming the core comprises compressing a ceramic powder into a solid part, at the completion of this stage of the process, the core may be in a green state; the core and the coating particles may be combined in an isopress mold; paragraphs [0039], [0041]); having exterior surface features (a surface and/or coating may be roughened or textured to provide for increased surface area of the silicon nitride material/coating; paragraph [0050]). McEntire does not disclose forming a green body from a feedstock comprising a colloidal mixture of powdered ceramic material including nanoparticles. Brodkin discloses forming a green body from a feedstock comprising a colloidal mixture of a powdered ceramic material including nanoparticles (colloidal spray deposition to form nanoparticulate materials of these invention into green shapes conforming to these substrates or molds; depositing nanoparticles into dies; sintering ceramic dental articles comprising nanopowders to nearly full density; paragraphs [0056], [0060], [0066]) and debinding and sintering the green body (green bodies were debinderized and sintered to nearly full density; paragraph [0061]).

Since none of the special technical features of the Groups I-VII inventions is found in more than one of the inventions, and since all of the shared technical features are previously disclosed by a combination of the McEntire and Brodkin references, unity of invention is lacking.