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(54) EXPANDABLE BONE IMPLANT

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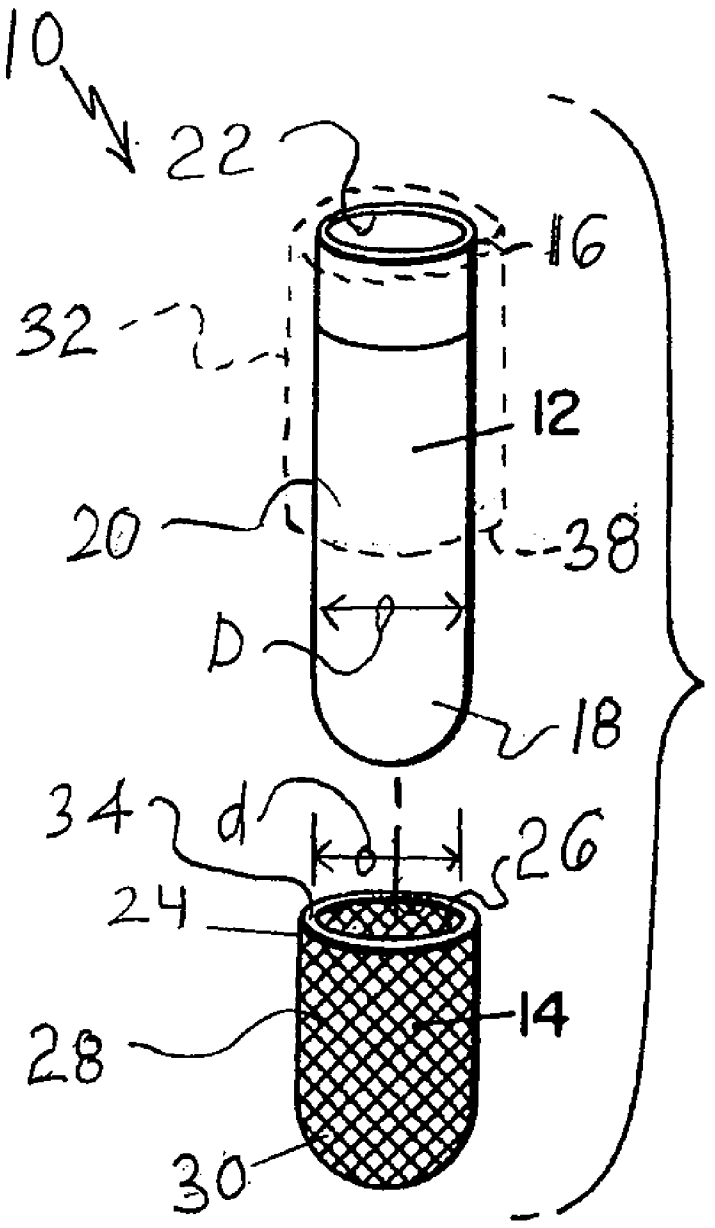
(57) **ABSTRACT**

An expendable bone implant has a first member with a coronal end portion configured for supporting a prosthesis. A second member is at least partially porous, engages the first member, and is configured to expand outwardly upon a longitudinal force being applied to at least one of the first and second members. This anchors the implant in bone before mastication forces are applied to the implant.



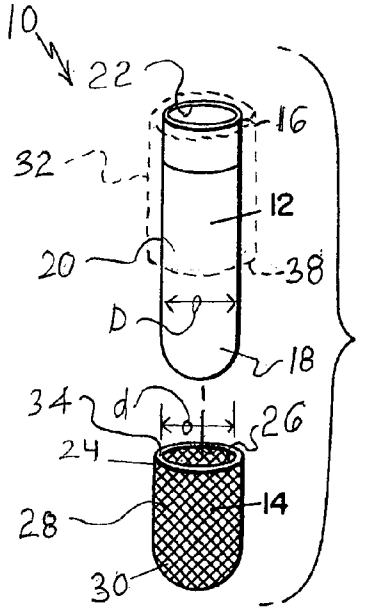


FIG. 1

FIG. 2

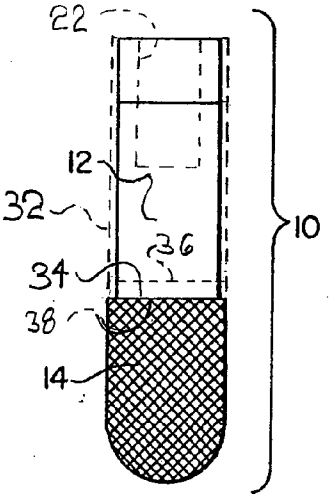
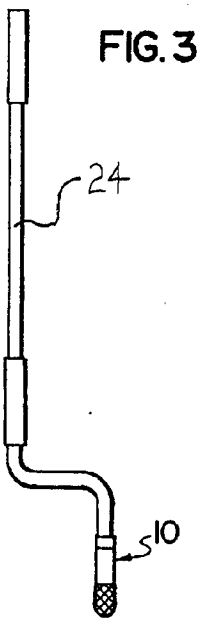


FIG. 3



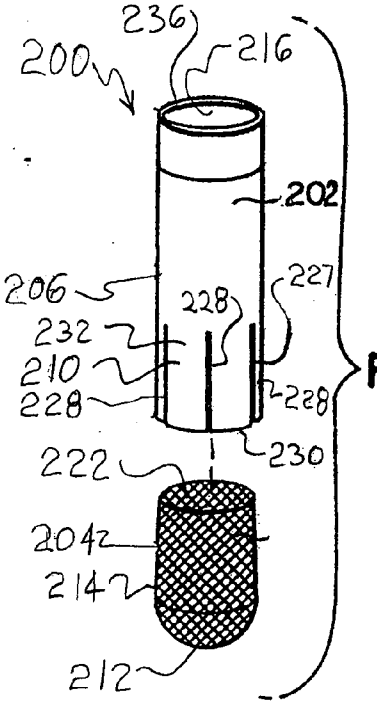


FIG. 4

FIG. 5

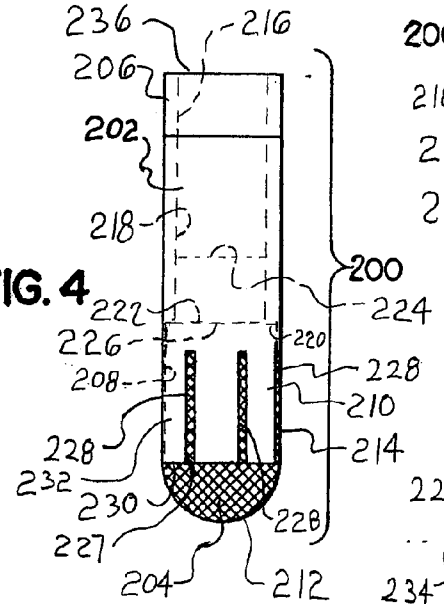


FIG. 7

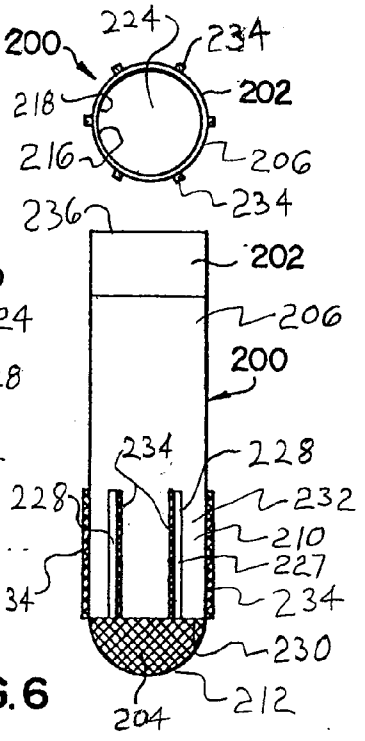
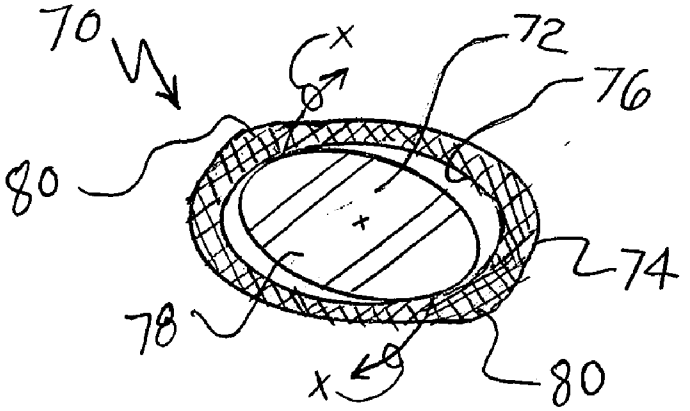


FIG. 6

FIG. 8



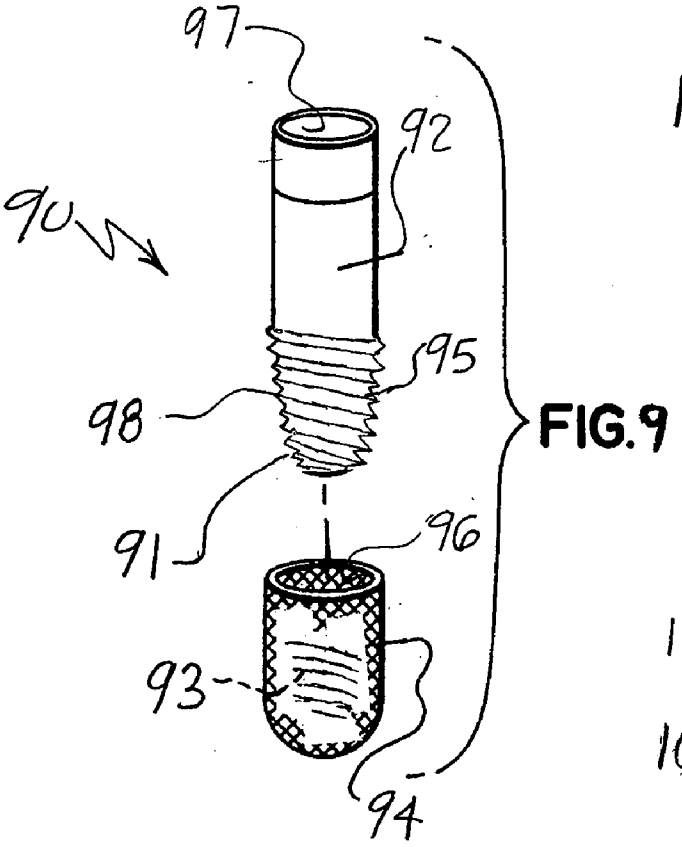


FIG. 9

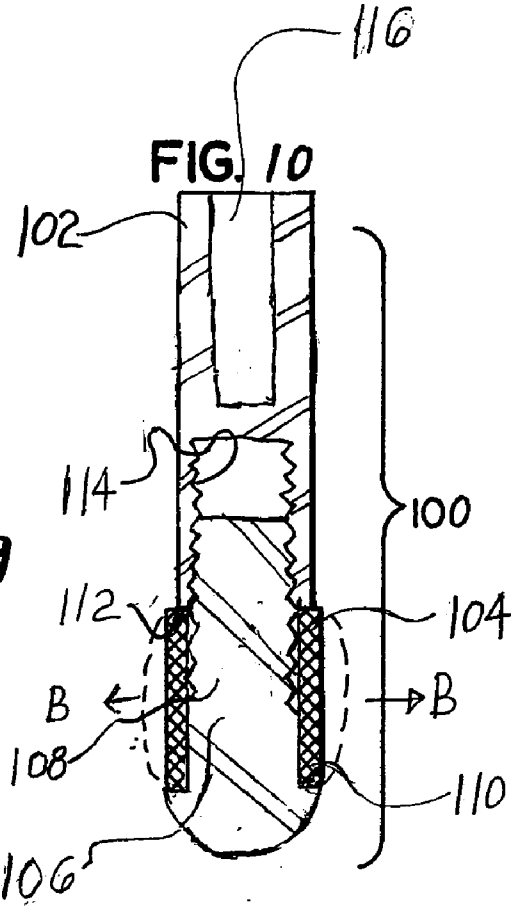
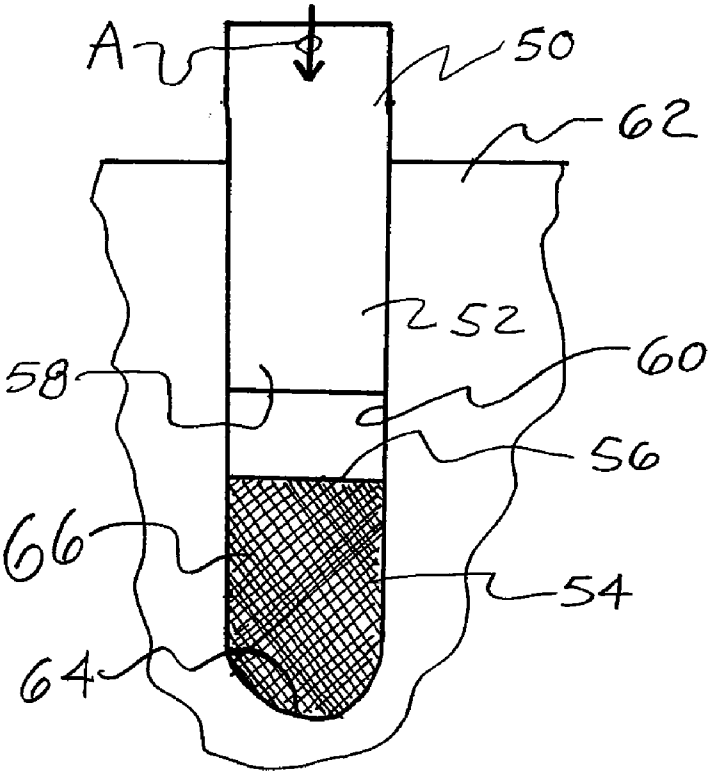


FIG. 10

FIG. 11



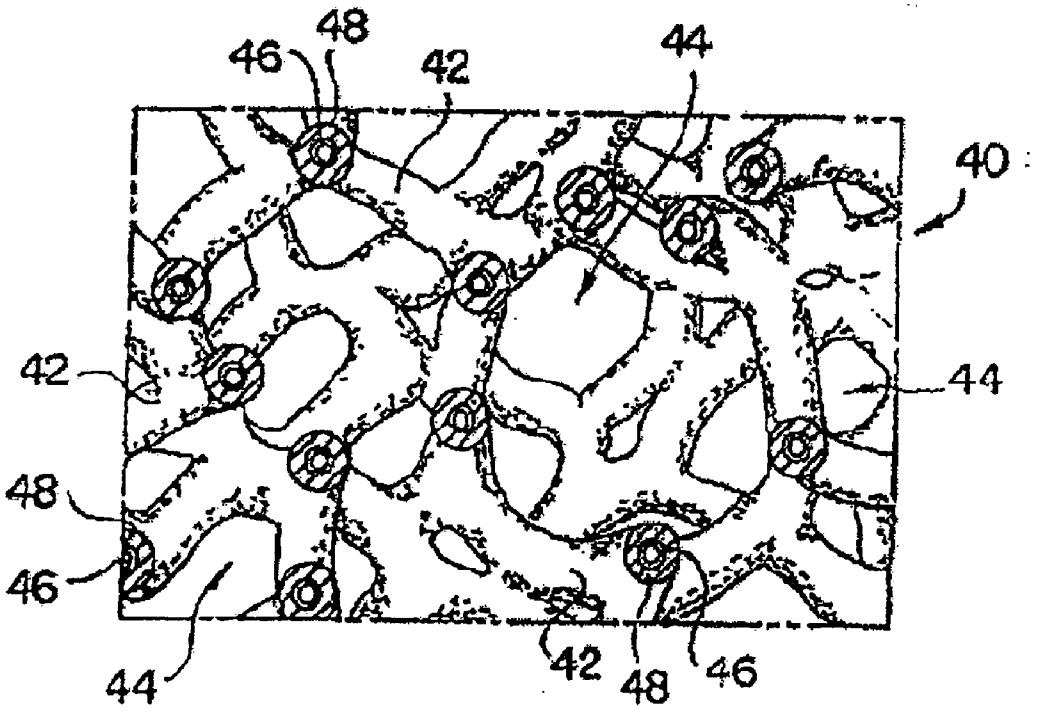


FIG. 12

EXPANDABLE BONE IMPLANT

FIELD OF THE INVENTION

[0001] The present invention relates to an implant for insertion into bone and, in particular, an expandable bone implant having improved osseointegration features.

BACKGROUND OF THE INVENTION

[0002] One type of bone implant is a dental implant or endosseous root form implant which is surgically implanted into a patient's upper or lower jaw to directly or indirectly anchor and support prosthetic devices, such as an artificial tooth. The implants are usually placed at one or more edentulous sites in a patient's dentition at which the patient's original teeth have been lost or damaged in order to restore the patient's chewing function. In many cases, the implant anchors a dental abutment, which in turn provides an interface between the implant and a dental restoration. The restoration is typically a porcelain crown fashioned according to known methods.

[0003] The implant is usually either threaded or press-fit into a bore which is drilled into the patient's mandible or maxilla at the edentulous site. The implant is inserted by applying a force to the coronal end of the implant in an insertion direction.

[0004] A patient typically prefers to leave after initial surgery with some type of restoration mounted on the implant, which transfers occlusive loads to the implant. Also, it has been shown that in many instances, healing of both soft and hard tissue is improved if the implant is loaded after surgery through a restoration. While the implant rarely receives the full load of occlusion during this healing phase and even with the restoration, the loading is sufficient to displace the implant. Thus, threads are used to achieve initial stability. Before biologic integration has time to take place, the thread resists tension, twisting or bending loads the implant might be subjected to.

[0005] The surgical procedure for inserting the threaded implants, however, can be complicated and requires that the threaded implants be turned into place, which further requires the use of special tools and inserts. The torque needed to place the implant into the jaw can be high and may require tapping of the bore on the jaw, which adds yet another step to the surgical procedure where tapping typically is not desired. Also with threaded implants, it is often difficult to achieve optimal esthetics because the geometry of the thread establishes a fixed relationship between the final vertical and rotational orientation of the implant such that a vertical adjustment of the implant requires a rotational adjustment and vice-versa. Thus, a prosthetic held at an ideal rotational orientation by the implant may not have the ideal vertical position.

[0006] Alternatively, although a press fit implant has a much simpler surgical procedure, the current press fit designs provide very little initial stability and are not well suited for early and immediate loading procedures that are currently used in dentistry.

[0007] The body of the dental implant has commonly been formed of titanium metal or titanium alloys. Titanium metals and alloys may act to enhance bone attachment to the surface of the dental implant. However, the titanium metals and alloys are orders of magnitude higher in stiffness than human bone and as a result absorb much of the mastication forces introduced in the mouth. This absorption of the forces by the titanium dental implants can result in inadequate stimulation of the surrounding bone tissue in the jaw, which over extended periods of time can cause the bone tissue to be resorbed by the body resulting in saucerization of the bone, or bone die-back. Over time, this bone die-back can cause the dental implant to loosen within its hole and even cause infection to the area. Accordingly, a press-fit implant is desired that provides sufficient initial stability while also providing improved osseointegration.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIG. **1** is an exploded, side perspective view of a first embodiment of an implant according to the present invention;

[0009] FIG. **2** is a side elevational view of the implant of FIG. **1**;

[0010] FIG. **3** is a side elevational view of an osteotome according to the present invention and having the implant of FIG. **2** attached at its distal end;

[0011] FIG. **4** is an exploded, side perspective view of a second embodiment of an implant according to the present invention;

[0012] FIG. **5** is a side elevational view of the implant of FIG. **4**;

[0013] FIG. **6** is a side elevational view of the implant of FIG. **4** showing a porous component expanded through slots in a shell component;

[0014] FIG. **7** is a top view of the implant of FIG. **6**;

[0015] FIG. **8** is an upper, cross-sectional view of a third embodiment of an implant according to the present invention;

[0016] FIG. **9** is an exploded, side perspective view of a fourth embodiment of an implant according to the present invention;

[0017] FIG. **10** is a side cross-sectional view of a fifth embodiment of an implant according to the present invention;

[0018] FIG. **11** is a side, exploded view of a sixth embodiment of an implant according to the invention and shown on a bore in bone; and

[0019] FIG. **12** is an enlarged fragmentary view of a porous tantalum portion for any of the embodiments herein and in accordance with the present invention.

DETAILED DESCRIPTION

[0020] Referring to FIGS. **1-2**, an implant **10** is provided for insertion into a surgical site such as a bore on bone, and in the particular examples here, into a mandible or maxilla. The implant **10** is used to support an abutment, and a prosthesis is mounted on the abutment. While two-stage endosseous implants are shown that terminate at the alveolar ridge, it will be understood that the implants may alternatively be single-stage implants with an integrally formed transgingival region or a one-piece implant with an integral abutment.

[0021] Implant **10**, as well as other implants described herein, are press-fit implants and forego the use of threads as the main mechanism to engage bone. This permits these implants to be placed at a desired depth in bone by using a longitudinal driving force without the need to rotate the implant and while still forming sufficient initial stability to withstand mastication forces.

[0022] More specifically, implant **10** has a first, relatively rigid member or component **12**, and a second, expandable, porous member or component **14** that is at least partially porous. The rigid member **12** is positioned coronally of the

porous member **14** and has a coronal or proximal end portion **16** to directly or indirectly support a prosthesis. The porous member **14** engages an apical or distal end portion **18** of the rigid member **12** when it is placed in a bore in bone. With this structure, a longitudinal force may be applied to the rigid member **12** so that the rigid member **12** impacts against the porous member. This driving force causes the porous member **14** to expand radially outward (and apically) into the surrounding bone of the surgical site. Thus, this expansion occurs before mastication takes place so that the implant **10** is well settled and generally will not expand further during full load mastication.

[0023] The rigid member **12** is formed of a relatively strong, hard metal such as titanium. The porous material forming the porous member **14** is particularly suited to form an immediate strong, stable interference fit with surrounding bone while improving osseointegration of the bone into the porous member **14**. The porous member **14**, in one form is a porous tantalum portion **40** (shown on FIG. **12**), which is a highly porous biomaterial useful as a bone substitute and/or cell and tissue receptive material. An example of such a material is produced using Trabecular Metal™ technology generally available from Zimmer, Inc., of Warsaw, Ind. Trabecular Metal™ is a trademark of Zimmer Technology, Inc. Such a material may be formed from a reticulated vitreous carbon foam substrate which is infiltrated and coated with a biocompatible metal, such as tantalum, etc., by a chemical vapor deposition ("CVD") process in the manner disclosed in detail in U.S. Pat. No. 5,282,861, the disclosure of which is fully incorporated herein by reference. Other metals such as niobium, or alloys of tantalum and niobium with one another or with other metals may also be used.

[0024] As shown in FIG. **12**, porous tantalum structure **40** includes a large plurality of ligaments **42** defining open spaces **44** therebetween, with each ligament **42** generally including a carbon core **46** covered by a thin film of metal **48** such as tantalum, for example. The open spaces **44** between ligaments **42** form a matrix of continuous channels having no dead ends, such that growth of cancellous bone through porous tantalum structure **40** is uninhibited. The porous tantalum may include up to 75%-85% or more void space therein. Thus, porous tantalum is a lightweight, strong porous structure which is substantially uniform and consistent in composition, and closely resembles the structure of natural cancellous bone, thereby providing a matrix into which cancellous bone may grow to anchor implant **10** into the surrounding bone of a patient's jaw which increases stability. The rough exterior surface of such porous metal portion has a relatively high friction coefficient with adjacent bone forming the bore that receives the implant to further increase initial stability as alluded to above. This structure can produce superior aesthetic results by restricting movement of the implant. These implants can be placed without supplementary surgical procedures, such as bone grafting, and can be placed in areas where traditional implants have been less successful, such as with reduced or decayed alveolar sections.

[0025] Porous tantalum structure **40** may be made in a variety of densities in order to selectively tailor the structure for particular applications. In particular, as discussed in the above-incorporated U.S. Pat. No. 5,282,861, the porous tantalum may be fabricated to virtually any desired porosity and pore size, whether uniform or varying, and can thus be matched with the surrounding natural bone in order to provide an improved matrix for bone in-growth and mineralization. This includes a gradation of pore size on a single implant such that pores are larger on an apical end to match cancellous bone and smaller on a coronal end to match cortical bone, or even to receive soft tissue ingrowth. Also, the porous tantalum could be made denser with fewer pores in areas of high mechanical stress. Instead of smaller pores in the tantalum, this can also be accomplished by filling all or some of the pores with a solid material which is described in further detail below.

[0026] To provide additional initial mechanical strength and stability to the porous structure **14**, the porous structure **14** may be infiltrated with filler material such as a non-resorbable polymer or a resorbable polymer. Examples of non-resorbable polymers for infiltration of the porous structure **14** may include a polyaryl ether ketone (PAEK) such as polyether ketone ketone (PEKK), polyether ether ketone (PEEK), polyether ketone ether ketone ketone (PEKEKK), polymethyl methacrylate (PMMA), polyetherimide, polysulfone, and polyphenolsulfone. Examples of resorbable polymers may include poly lactic acid (PLA), poly glycolic acid (PGA), poly lactic co-glycolic acid (PLGA), polyhydroxybutyrate (PHB), polyhydroxyvalerate (PHV), and copolymers thereof, polycaprolactone, polyanhydrides, and polyorthoesters. The resorbable material would resorb as the bone grows in and replaces it, which maintains the strength and stability of the implant.

[0027] Regarding the initial stability, as the porous member **14** is inserted into the bore in bone, the porous material will bite into the bone by grating, chipping and/or flaking bone pieces off of the sidewalls of the bore in which the implant device is being placed. When the implant is press-fit into the bore rather than threaded into the bore, this "rasping" action may form slight recesses or indents within the bore sidewall in which the implant device sits. This restricts rotational or twisting motion of the implant device within the bore since the implant device does not have the clearance to rotate out of the indents and within the bore.

[0028] The rasping action also accelerates osseointegration onto the implant device and into the pores of the porous material due to the bone compaction into the pores. First, the grating of the bone structure causes the bone to bleed which stimulates bone growth by instigating production of beneficial cells such as osteoblasts and osteoclasts. Second, the bone pieces that fall into the pores on the porous material assist with bone remodeling. In the process of bone remodeling, osteoblast cells use the bone pieces as scaffolding and create new bone material around the bone pieces. Meanwhile osteoclast cells remove the bone pieces through resorption by breaking down bone and releasing minerals, such as calcium, from the bone pieces and back into the blood stream. The osteoblast cells will continue to replace the grated bone pieces from the pores and around the implant device with new and healthy bone within and surrounding the extraction site. The composite of in-grown bone and porous tantalum has elastic properties much closer to bone than a solid metal implant, creating a loading environment that is conducive to maintaining bone near the implant. Thus, with the porous material, the porous member **14**, and in turn the implant **10**, has increased resistance to twisting or rotation, allows for immediate or very early loading, and increases long-term stability due to the improved osseointegration. Such an implant with ingrown bone has stability greater than a comparably sized implant with only on-grown bone.

[0029] The properties of the porous material also enable expansion of the porous member **14** to anchor the porous member **14** into the surrounding bone. To expand the porous material for any of the implants described herein, the modulus of elasticity (i.e., the amount of deformation in the elastic region of the stress/strain curve when a given stress is applied) of the porous material, or at least that portion of the porous member that will expand, should be about 3 Gpa or less.

[0030] As the porous material of any of the implants described herein expands radially against the bone, the porous material cuts into the bone. This occurs because the outer surface of the porous material can be made to have trabeculi or sharp protrusions of metal that extend from the outer surface. These trabeculi are formed when a "cell" of the porous tantalum is cut leaving only a portion of each strut that make up a porous tantalum "cell." It is believed that the trabeculi, when compressed against the bone surface, cut into the bone because the porous tantalum metal can withstand greater stress than many types of bone tissue. The result of this digging in or rasping action with the cut struts further increases the initial stability of the implant in the surgical site in addition to the uncut struts described above.

[0031] To provide this cutting action as the porous member for any of the implants described herein expands, the compressive strength of the porous metal should be from about 50 to about 90 MPa, which is relatively higher than the compressive strength of cancellous bone which is about 10 to about 50 MPa. The area of contact between each trabeculi and the bone will be very small due to the geometry of the trabeculi as described above. This will result in high stress (load/area) when even moderate loads are applied. Since the amount of stress the porous tantalum metal can achieve prior to yield is higher than the surrounding bone tissue, the porous material will dig into the bone.

[0032] Referring again to FIGS. **1-2**, in one form, the rigid member **12** is generally bullet-shaped with a cylindrical outer surface **20** that terminates in the apical end portion **18** which is rounded. The outer surface **20** can be smooth but may be roughened or otherwise treated to promote bone growth or restrict bacterial growth. The coronal end portion **16** of the rigid member **12** is open to an inner longitudinal cavity **22** for receiving a driving device such as an osteotome **24** (shown in FIG. **3**) and/or for receiving fasteners to secure an abutment to the implant **10**. The longitudinal cavity **22** may have a circular cross-section for the purpose of receiving a longitudinal force from the driving tool. The longitudinal cavity **22**, however, may also have a non-circular cross-section, or have a non-circular portion, such as polygonal, to receive an abutment, a fastener holding an abutment, or to limit rotation of the driving tool relative to the implant **10** for convenience while inserting the implant **10** in the bore.

[0033] The porous member **14** is generally cup-shaped and forms a coronally accessible, longitudinally extending, interior cavity **26**. The porous member **14** has a generally cylindrical wall **28** as well as a rounded apical end portion **30** that cooperatively defines the cavity **26**. The apical end portion **30** has a shape that corresponds to the shape of apical end portion **18**. To facilitate expansion, the wall **28** should not be too thick, and in one aspect, has a thickness from about 0.020 inches to about 0.040 inches.

[0034] The apical end portion **18** is configured to be inserted into the cavity **26** to expand the porous member **14**. Thus, in one form, an inner diameter d of the porous member **14** and defined by the cavity **26** may be slightly smaller than an outer diameter D of the rigid member **12**. Since the modulus of elasticity of the porous member **14** is significantly less than the modulus of elasticity of the rigid member **12**, urging the rigid member **12** apically into the cavity **26** will expand the porous member **14** generally radially outward and against the bone in the bore.

[0035] To place the implant **10** in a bore in bone, first, the practitioner uses a tool, which may be the same osteotome **24** or a separate tool, received in the cavity **26** to press the initially separate porous member **14** into the bore by applying a longitudinal force on the tool. Thus, the porous member **14** is placed in the bore before placing the rigid member **12** in the bore. Once the porous member **14** is in place, the practitioner uses the osteotome **24** to engage the rigid member **12** to create a longitudinal force and press or tap the rigid member **12** into the bore and subsequently into the cavity **26** of the porous member **14**. As mentioned above, this action will expand the porous member **14** radially outward as well as compress the apical end portion **30** of the porous member **14** between the rigid member **12** and a bottom of the bore (similar to the bottom **64** of the bore **60** shown in FIG. **11**). This forces the porous member **14** to cut into the adjacent bone defining the bore and create initial stability in multiple directions as described above. Once the apical end portion **18** is fully inserted into the cavity **26**, the rigid member **12** forms a core for the porous member **14**, and the porous member **14** at least generally covers the apical end portion **18**.

[0036] In an alternative aspect, however, the rigid member **12** and the porous member **14** can be assembled together before insertion into the bore, and even preassembled by the manufacturer or supplier before the implant **10** is received by the practitioner. In this case, the porous member **14** is at least partially mounted on the apical end portion **18** of the rigid member **12** before the two members **12** and **14** are placed in a bore in bone. If the implant **10** is assembled first before it is inserted into the bore, the rigid member **12** may be driven into the porous member **14** a sufficient depth just to retain the porous member **14** on the rigid member **12** without significantly expanding the porous member **14**. Once the implant **10** is placed into the bore, then the osteotome **24** can be pressed with a longitudinal force sufficient to expand the porous member **14** radially outward and into the bone.

[0037] As another option, the porous member **14** can be secured to the rigid member **12** by a loose press-fit that permits the porous member **14** to be separated from the rigid member **12** easily, such as by hand. In other words, the apical end portion **18** of the rigid member **12** is dimensioned to easily slip in and out of cavity **26**. In this case, the diameters d and D of the cavity **26** and rigid member **12** are sufficiently close to form an interference fit that holds the members **12** and **14** together without significant expansion until the implant is inserted and assembled in the bore in the bone. Once inserted, significant force may be applied to the osteotome **24** in multiple directions to press the porous member **14** against the surrounding bone forming the bore.

[0038] While an interference fit between the rigid member **12** and porous member **14** is mentioned, it will be understood that adhesives, welding, and/or heat may be used to additionally or alternatively connect the two parts together, especially when the implant **10** is to be preassembled.

[0039] It will also be appreciated that the porous member **14** may alternatively extend over most, or substantially all, of the coronal-apical length of the implant **10**, or the porous member **14** may only cover certain sections of the rigid mem-

ber **12** instead of only cupping the apical end **18** of rigid member **12**. Thus, it may be cylindrical, and the rigid member **12** may or may not extend all the way through the porous member **14** to form an apical end of the implant **10**. Also, the apical end portion **30** of the porous member **14** may be provided in varying desired thicknesses (in the coronal-apical direction) to provide different porous lengths extending apically from the apical end portion **18** of the rigid member **12**. Otherwise, the total assembled length of implant **10** may be provided in different desired dimensions by varying the length of rigid member **12**.

[0040] Alternatively, a wide portion **32** (shown in dashed line on FIGS. **1-2**) of the rigid member **12** may be provided to additionally engage a coronally facing, annular surface **34** of the porous member **14**. Specifically, the wide portion **32** has a diameter larger than a diameter of the apical end portion **18** to form an apically facing, annular shoulder **38** extending radially outward from the apical end portion **18**. The shoulder **38** engages the surface **34** when the rigid member **12** is pressed apically against the porous member **14**. In this case, when the practitioner impacts the driving tool **24** longitudinally on the apical end portion or driving end **16** of the rigid member **12**, the wall or sidewall **28** of the porous member **14** is compacted between the shoulder **38** of the rigid member **12** and the bottom of the bore (similar to bottom **64** shown in FIG. **11**) in which it is disposed. This causes the sidewall **28** to bulge or expand radially outward to contact, and cut into, surrounding bone.

[0041] While the wide portion **32** is shown to extend to the coronal end portion **16** of the rigid member **12**, it will be understood that instead, the wide portion **32** may extend coronally from shoulder **38** any coronal-apical distance along the length of the rigid member **12** that is sufficient to transfer adequate force to the porous member **14**. In one example, the wide portion **32** is in the form of a relatively thin flange **36** (as shown in dashed line in FIG. **2**).

[0042] Referring to FIG. **11**, in another alternative basic form, an implant **50** has a rigid member **52** that engages a porous member **54** at least partially made of the porous material as described above and as with the implant **10**. Here, however, the porous member **54** does not have a main cavity. Instead, the porous member **54** has a coronally facing surface **56** for engaging an apical end portion **58** of the rigid member **52**. As with implant **10**, either the members **52** and **54** are placed separately into the bore **60** as shown in FIG. **11**, or the members **52** and **54** are assembled before insertion into a bore **60** in bone **62**. In the former case, the porous member **54** is placed in the bore **60**, and the rigid member **52** is then placed in the bore **60** and pressed or tapped in a longitudinal direction (as represented by arrow 'A' on FIG. **11**) until the rigid member **52** engages the porous member **54** so that the porous member **54** is compacted between a bottom **64** of the bore **60** and the rigid member **52**. This causes a sidewall **66** of the porous member **54** to bulge or expand radially outward to engage the surrounding bone. The porous member **54** also is pressed apically to cut into the bone on the bottom **64** of the bore **60**.

[0043] If the members **52** and **54** are to be preassembled before insertion into the bore **60**, the members **52** and **54** may be attached to each other by interlocking structure on the apical end portion **58** and surface **56** or by other ways such as fasteners, adhesives, welding, heat, and so forth. Otherwise, once the implant **50** is placed in the bore **60** the procedure is the same as if the members **52** and **54** were initially separate. Instead of being completely porous, porous member **54** may have a core of a different solid material or have its pores filled with a different material as described above as long as it does not significantly interfere with the required compression of the porous member **54** for its radial expansion.

[0044] Referring now to FIG. **8**, as yet another alternative form, an implant **70** has a similar structure to implant **10** including a rigid member **72** and a porous member **74** with a longitudinal cavity **76** for receiving the rigid member **72**. Except here, the rigid member **72**, or at least an apical end portion **78** of the rigid member **72** that extends into cavity **76**, and the porous member **74** have transverse cross sections that are non-circular. While other shapes are contemplated (such as polygonal, other shapes with flat sides, other irregular curved shapes, or combinations of the two), in the illustrated form, the cross sections of the apical end portion **78** and the porous member **74** are oval or elliptical. So configured, once the apical end portion **78** extends within the cavity **76** in a corresponding orientation as that of the porous member **74** (i.e., where the major axes of both cross sections extend generally in the same direction), the rigid member **72** may be rotated relative to the porous member **74**, as illustrated by arrows X. The porous member **74** is sufficiently thin such that the rotation of the rigid member **72** causes the major diameter of the apical end portion **78** to be forced toward or into the minor diameter of the porous member **74**, which causes the porous member **74** to bulge or expand radially outward (as shown by bulges **80**) to engage the surrounding bone.

[0045] Referring to FIG. **9**, an implant **90** has further alternative features that may also be applied to implant **10**. The implant **90**, as with implant **10**, comprises a rigid member **92** and a porous member **94** with a cavity **96** for receiving an apical end portion **98** of the rigid member **92**. Here, however, the apical end portion **98** can further include threads **91** for screwing the rigid member **92** into the cavity **96**. The cavity **96** may or may not have a threaded portion **93** for engaging the threads **91**. Whether or not the apical end portion **98** is threaded, the apical end portion **98** may be tapered such that the apical end portion **98** is sloped inward as it extends apically. The taper **95** helps to locate the apical end portion **98** in the cavity **96** and to expand the porous member **94** when the tapered apical end portion **98** has diameters that are larger than the inner diameter defining the cavity **96** as the taper **95** at the apical end portion **98** extends coronally. To expand the porous member **94** once placed in a bore in bone, the rigid member **92** is driven longitudinally and apically, albeit by rotating the rigid member **92**, into the porous member **94** to expand the porous member **94** generally radially outward and onto the surrounding bone. In this case, a coronal cavity **97** on rigid member **92** may be non-circular to receive a rotational force from a driving tool.

[0046] Referring to FIG. **10**, in another form, an implant **100** has three pieces instead of two. The implant **100** includes a first, coronal, shell or rigid member **102**; a second, porous member **104** made of the same material as porous member **14**; and a third, apical, core member **106** threaded to the shell member **102**. The porous member **104** is cylindrical and is mounted around a core portion **108** of the core member **106**. The porous member **104** is clamped between an annular ledge **110** extending radially outward from the core portion **108** on the core member **106** and an annular, apical end surface **112** formed by the shell member **102**.

[0047] The core portion **108** is threaded and fits into an interiorly threaded bore **114** defined by the shell member **102**

and that is apically accessible. The core portion **108** has a coronal-apical length sufficient to extend through the porous member **104** and protrude coronally from the porous member **104** to engage the threaded bore **114**. The shell member **102** has a coronally accessible cavity **116** for receiving a driving tool for rotating the shell member **102** to thread the shell member **102** onto the core member **106**. This rotation adjusts the shell member **102** and core member **106** toward each other to longitudinally compress the porous member **104** between the surface **112** and shoulder **110**, causing the porous member **104** to bulge or expand radially outward, as indicated by arrows B, to engage the surrounding bone. The threaded bore **114** is sufficiently deep to accommodate the insertion length of the core portion **108**.

[0048] Alternative configurations are apparent such as where the core portion is on the coronal member rather than the apical member, the porous member extends additionally or alternatively on other sections of the coronal-apical length of the implant **100**, and/or the core member and shell member are attached to each by other than threads such as a press-fit or by fasteners.

[0049] Referring to FIGS. **4-7**, in a different form, an implant **200** is similar to implant **10** in that it has a first, coronal, rigid or shell member **202** and a second, porous member **204** made of similar materials as that mentioned above for implant **10**. Here, however, shell member **202** forms an outer shell to cover at least a part of the second, porous member **204**, and rather than being cup-shaped with an interior cavity, the porous member **204** is a relatively solid piece as with porous member **54** on implant **50**. The porous member **204** is at least partially porous, but in the illustrated embodiment substantially porous, or alternatively may have a core of a different material or the porous material may be injected to form a core with a different filler material as mentioned previously.

[0050] The shell member **202** has a body **206** that defines a longitudinal or axial cavity **208** open at an apical or distal end portion **210** of the shell member **202**. The porous member **204** is at least partially disposed within the longitudinal cavity **208** when assembled together, and in the illustrated form, extends apically from the shell member **202** to form the apical end **212** of the implant **200**. The porous member **204** may also have a sidewall **214** that tapers inwardly as it extends coronally to assist with locating the porous member in cavity **208** and expanding radially outward when pressed to the shell member **202**.

[0051] The longitudinal cavity **208** extends at least along the apical end portion **210** but may alternatively extend the entire length of the shell member **202** so that the longitudinal cavity **208** forms a coronally accessible hole **216** for receiving a driving tool **24** (FIG. **3**). In this case, the interior surface **218** (shown in dashed line) defining the longitudinal cavity **208** has a jog or annular shoulder **220** to engage a coronal surface **222** of the porous member **204**. With this configuration, the shell member **202** will engage the porous member **204** at the shoulder **220** to impact the porous member **204** as the shell member **202** is tapped or driven apically on the porous member **204**. Otherwise, with the longitudinal cavity **208** open the entire length of the shell member **202**, the driving tool may additionally or alternatively impact the porous member **204** directly as explained in greater detail below.

[0052] Alternatively, an interior wall **224** (shown in dashed line) divides the longitudinal cavity **208** from the coronal hole **216** that receives the driving tool. In this case, the apical surface **226** of the interior wall **224** engages the porous member **204**.

[0053] The body **206** of the shell member **202** also has at least one opening **227** providing generally radial access to the longitudinal cavity **208** to permit the porous member **204** to extrude radially outward and through the openings to engage bone. In one form, the openings are generally longitudinally extending slots **228** extending along the apical end portion **210** to an apical end surface **230** of the shell member **202**. In the illustrated form, a plurality of longitudinal slots **228** are uniformly spaced around the body **206**. Here, six slots **228** are provided but any desired number of slots may be used. The height of the slots **228** may vary, either uniformly or from each other, and may extend at least a majority of the length of the body **206** or even substantially the entire length of the body **206** if desired. In the illustrated form, the porous member **204** extends longitudinally within longitudinal cavity **208** for a length at least sufficient to engage the entire length of the slots **228** as shown in FIG. **5**.

[0054] In order to permit the porous member **204** to expand or extrude through the slots **228**, or at least into the slots **228** and to the exterior of the shell member **202**, the body **206** is made of a cylindrical wall **232** that defines the slots **228** and that has a thickness at least in the vicinity of the slots **228** of about 0.010 inches or less. So configured, the porous member **204** need only expand 0.010 inches or more to engage bone. The body **206** should not bend significantly if at all. In one form, the body **206** may be made of titanium and has a stiffness of about 110 GPa compared to the 3 GPa of the porous member **204** and as described above for porous member **14**. Expanding or extruding the porous member **204** through the slots **228** will form an outwardly and radially extending porous rib **234** (as shown on FIG. **6**) at each slot **228** for engaging surrounding bone. Each rib **234** generally runs longitudinally along the shell member **202** to correspond to the shape of the slot **228**.

[0055] With the structure of implant **200** described, the porous member **204** can be separately placed in a bore in bone (such as the bore **60** shown in FIG. **11**), and the shell member **202** is placed subsequently in the bore and onto the porous member **204**. In another form, however, the porous member **204** is placed in the longitudinal cavity **208** before the implant **200** is placed in the bore in bone. In either case, the porous member **204** may be secured within the longitudinal cavity **208** by an interference fit, or alternatively, the porous member **204** merely initially has a loose press-fit within the longitudinal cavity **208**. In the latter case, and when the porous member **204** is provided in different coronal-apical lengths, for example, the practitioner can replace the porous member **204** from the shell member **202** until a porous member **204** of an adequate coronal-apical length is selected.

[0056] Once the porous member **204** is mounted on the shell member **202**, the osteotome **24** or other driving tool is mounted on the driving end of the shell member **202** or more specifically, in the coronal hole **216** on the shell member **202** to place the implant **200** within the bore in the bone (such as that shown in FIG. **11**). As the osteotome **24** is driven or tapped in an insertion direction, the osteotome **24** engages the interior wall **224**, if present, and/or a coronal end surface **236** of the shell member **202**. It will be understood that the interior surface **218** of the shell member **202** may also have shoulders or ledges to receive the driving member or osteotome **24** for driving the shell member **202** apically.

[0057] Once the porous member **204** is seated on a bottom of the bore in the bone, further impacting the driving tool on the driving end of the shell member **202** with a longitudinal force compacts the porous member **204** between the shell member **202** and the bottom of the bore. This, in turn, causes the sidewall **214** of the porous member **204** to expand radially outward and extrude into or through the slots **228** to form the ribs **234** to engage surrounding bone (as shown in FIG. **6**).

[0058] For the alternative configuration where the longitudinal cavity **208** extends the length of the shell member **202** and the interior wall **224** is not present, the driving tool **24** may directly engage the driving end or coronal surface **222** of the porous member **204**. In this case, the driving tool engages the coronal end surface **236** of the shell member **202**, engages a shelf or shoulder on the interior surface **218**, or has an interference fit with the interior surface **218** for initial placement of the implant **200** in the bore in bone. Once so disposed, further impact of the driving tool on the driving end (or in this case, the porous member **204**) compacts the porous member **204** between the driving tool and the bottom of the bore. This expands the sidewall **214** of the porous member **204** radially outward and into or through the slots **228** to form the ribs **234**.

[0059] The expanded porous ribs **234** cut into the bone as described above and anchors the implant **200** in the bore in which it is disposed to provide stable initial stability to receive immediate mastication forces. Since the ribs **234** extend into the cortical bone, such configuration provides the implant **200** an additional torsional stability. The porous nature of the material forming the ribs **234** also aids in enhancing the speed of osseointegration of the implant **200** with the bone as described above.

[0060] The above described press-fit dental implants may be conventionally machined or cut using Electrical Discharge Machining (EDM). The above described press-fit dental implants may also be made by using the net-shape manufacturing process as owned by Zimmer Trabecular Metal Technologies, Inc.

[0061] While this invention may have been described as having a preferred design, the present invention can be further modified within the spirit and scope of this disclosure. This application is therefore intended to cover any variations, uses, or adaptations of the invention using its general principles. Further, this application is intended to cover such departures from the present disclosure as come within known or customary practice in the art to which this invention pertains and which fall within the limits of the appended claims.

What is claimed is:

1. An implant comprising:

a first member having a coronal end portion configured for supporting a prosthesis; and

a second member, being at least partially porous, engaging the first member, and configured to expand outwardly upon a longitudinal force applied to at least one of the first and second members to anchor the implant in bone before mastication forces are applied to the implant.

2. The implant of claim **1** wherein the second member includes porous metal.

3. The implant of claim **1** wherein the second member includes tantalum.

4. The implant of claim **1** wherein the implant is a dental implant.

5. The implant of claim **1** wherein the second member is initially secured to the first member only by a loose press-fit that permits the second member to be separated from the first member by hand.

6. The implant of claim **1** wherein the second member is initially separate from the first member for placement in a bore in bone before the first member is assembled to the second member.

7. The implant of claim **1** wherein the second member has a cavity, and wherein the first member has an apical end portion configured for insertion into the cavity.

8. The implant of claim **7** wherein the cavity defines an inner diameter of the second member, and wherein the apical end portion has an outer diameter that is greater than the inner diameter so that inserting the apical end portion into the cavity expands the second member radially outward.

9. The implant of claim **7** wherein the apical end portion is tapered inwardly as it extends apically for being disposed within the cavity.

10. The implant of claim **7** wherein the apical end portion comprises threads for engaging the second member.

11. The implant of claim **1** wherein the first member has an apical end portion and the second member is generally cup shaped for at least generally covering the apical end portion of the first member.

12. The implant of claim **1**, wherein the second member has a generally cylindrical wall with a thickness of about 0.020 inches to about 0.040 inches.

13. The implant of claim **1**, wherein the second member has a modulus of elasticity that is less than a modulus of elasticity of the first member.

14. The implant of claim **1** wherein the second member has sufficient strength to cut into bone during expansion of the second member.

15. The implant of claim **1** wherein the second member has a compressive strength in a range from about 50 MPa to 90 MPa.

16. The implant of claim **1** wherein the second member has a stiffness of about 3 Gpa or less.

17. The implant of claim **1** wherein the first member comprises a body defining a generally longitudinal cavity and at least one opening on the body providing generally radial access to the longitudinal cavity, and

wherein the second member is at least partially disposed within the longitudinal cavity and being configured to expand radially into the at least one opening.

18. The implant of claim **17** wherein each at least one opening forms a generally longitudinally extending slot so that the second member expands to form a generally longitudinally and radially extending rib through each slot for engaging bone.

19. The implant of claim **17** further comprising a plurality of slots uniformly spaced around the body.

20. The implant of claim **17** wherein the first member has an apical end surface, and wherein the slot formed by each at least one opening longitudinally extends to the apical end surface.

21. The implant of claim **17** wherein the body has a cylindrical wall defining the cavity and the at least one opening, and wherein the wall has a thickness at least in the vicinity of the at least one opening of about 0.010 inches or less.

22. The implant of claim **17** wherein the slot formed by each at least one opening generally extends at least a majority of the length of the first member.

23. The implant of claim **17** further configured to be placed in a hole with a bottom in bone, and wherein the second member has a sidewall and wherein the first member has a driving end configured for receiving a driving tool so that impacting the driving end with the driving tool compacts the second member between the first member and the bottom of the hole to expand the sidewall generally radially outward.

24. The implant of claim **17** further configured to be placed in a hole with a bottom in bone, and wherein the second member has a sidewall and a driving end configured for receiving a driving tool so that impacting the driving end with the driving tool compacts the second member between the driving tool and the bottom of the hole to expand the sidewall generally radially outward.

25. The implant of claim **1** wherein the first member has a longitudinal cavity, and wherein the second member has a sidewall tapered inwardly as it extends coronally for locating the second member within the longitudinal cavity.

26. The implant of claim **1** further comprising a third apical member adjustably engaging the first member, the second member being clamped between the first and third members so that adjusting the first and third members towards each other longitudinally compresses the second member and expands the second member generally radially outward.

27. The implant of claim **26** wherein the first and third members are threaded to each other.

28. The implant of claim **1** wherein the second member is generally non-circular and has a longitudinal cavity for receiving the first member, and wherein rotating the first member within the second member causes the second member to expand generally radially outward.

29. The implant of claim **28** wherein the first member and second member are elliptical or oval.

30. A method of anchoring a bone implant in a bore in bone comprising:

providing a first member with a distal end portion and a second member defining a cavity and being at least partially porous;

inserting the second member into the bore; and

expanding at least a portion of the second member radially outward and toward the bone by driving the distal end portion of the first member into the cavity of the second member.

31. The method of claim **30** wherein the cavity defines an inner diameter of the second member, and wherein an outer diameter of the first member is greater than the inner diameter of the second member.

32. The method of claim **30** wherein the second member includes tantalum.

33. The method of claim **30** wherein the second member is placed in the bore before placing the first member in the cavity of the second member.

34. The method of claim **30** wherein the implant is a dental implant.

35. The method of claim **30** wherein the second member comprises a cylindrical wall about 0.020 to about 0.040 inches thick.

36. A method of anchoring a bone implant in a bore in bone comprising:

providing a bone implant having an inner porous member and an exterior shell member defining a longitudinal cavity and at least one generally radial opening from the cavity;

placing the inner porous member at least partially within the longitudinal cavity of the exterior shell member;

placing the implant in the bore; and

expanding the porous member to extrude through the at least one generally radial opening of the shell member to engage bone.

37. The method of claim **36** wherein the at least one opening comprises a plurality of generally longitudinally extending slots so that expanding the porous member forms ribs that extend generally radially outward from the shell member and extend generally longitudinally along the shell member.

38. The method of claim **36** wherein the porous member extends apically from the shell member.

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