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(54) **IMPLANT SYSTEMS WITH SWIVEL JOINTS FOR SINUS LIFT AND BONE AUGMENTATION**

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A61C 1/00	(2006.01)

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USPC **433/174**

(57) **ABSTRACT**

Apparatus is provided that includes a dental implant having a distal implant portion that extends from a distal implant end along up to 50% of a longitudinal length of the implant, the implant shaped so as to define a lumen through the implant, which lumen has at least one distal opening through a distal external surface of the distal implant portion. The apparatus further includes a swivel joint having first and second joint portions defining first and second joint ports, respectively, the swivel joint arranged so as to define a fluid path from the second joint port to the first joint port via the second and first joint portions, which are arranged to be rotatable with respect to one another such that the fluid path is preserved during rotation. The fluid path through the swivel joint is in fluid communication with the lumen via the first joint port.

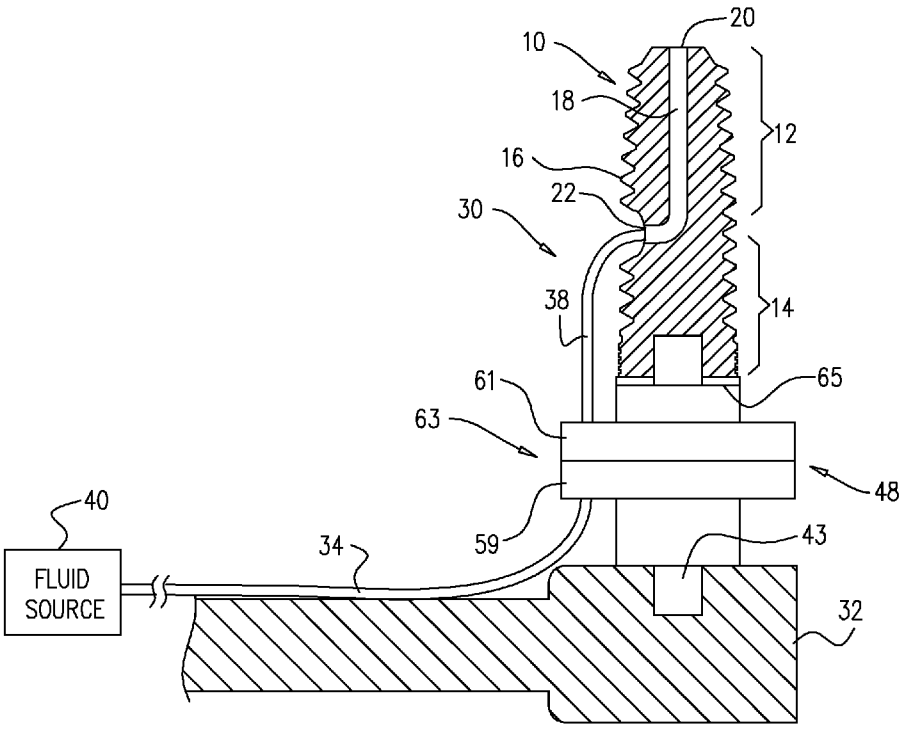


FIG. 1D

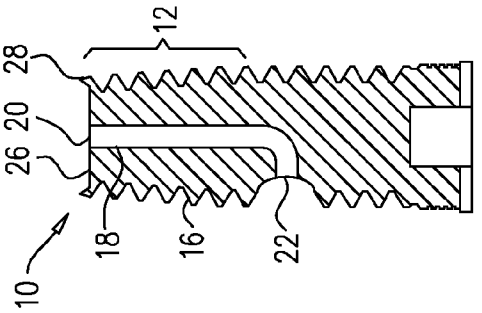


FIG. 1C

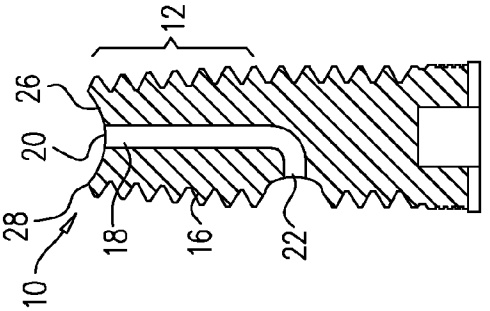


FIG. 1B

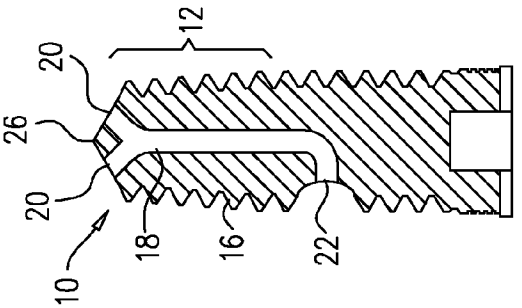
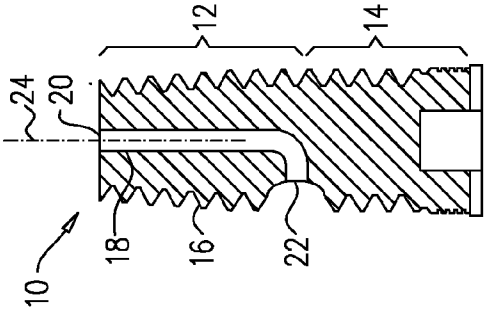


FIG. 1A



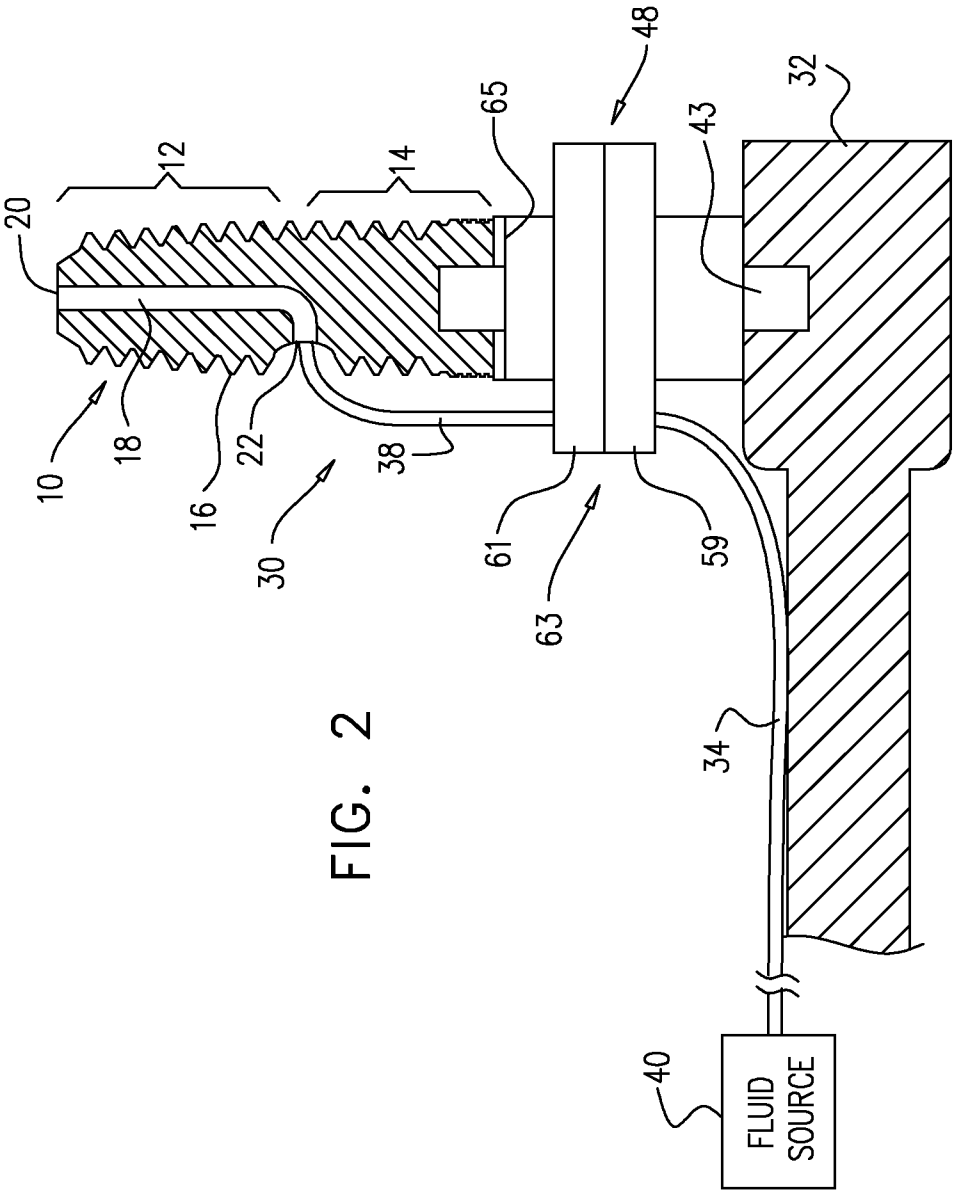


FIG. 2

FIG. 3A

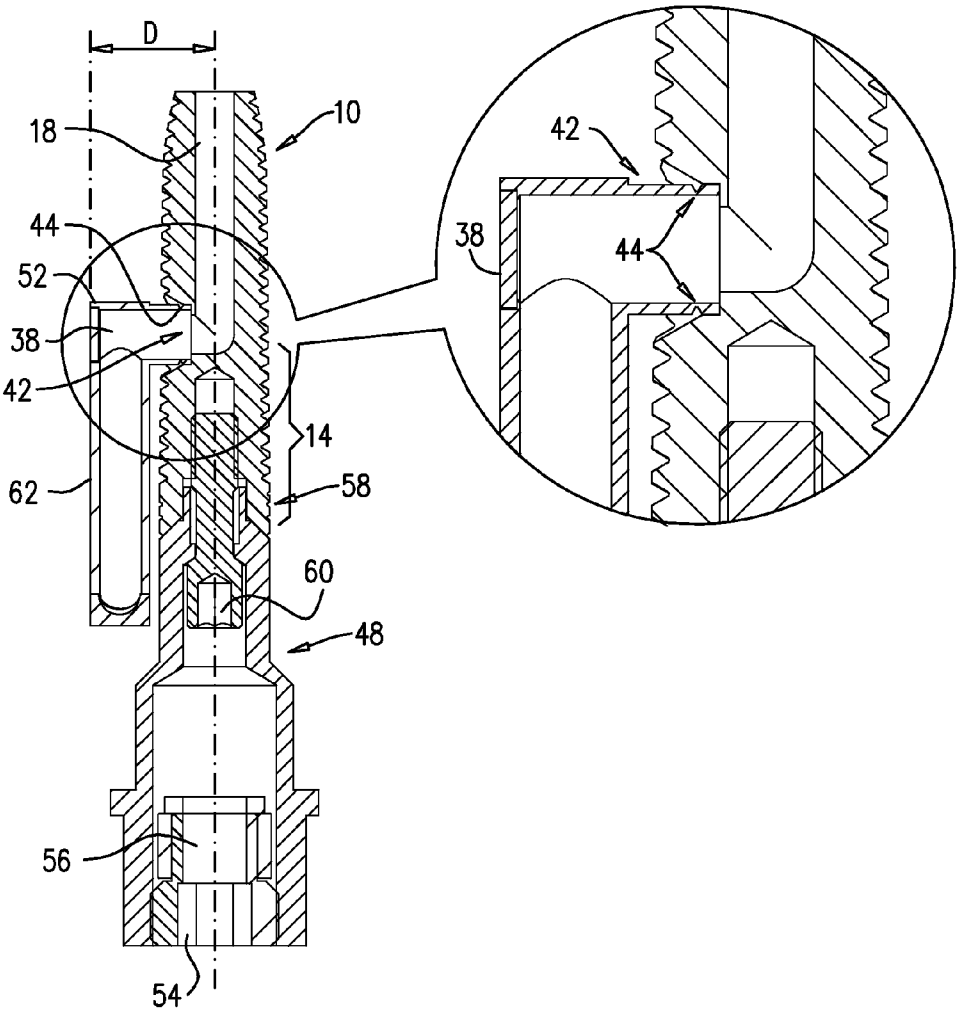


FIG. 3B

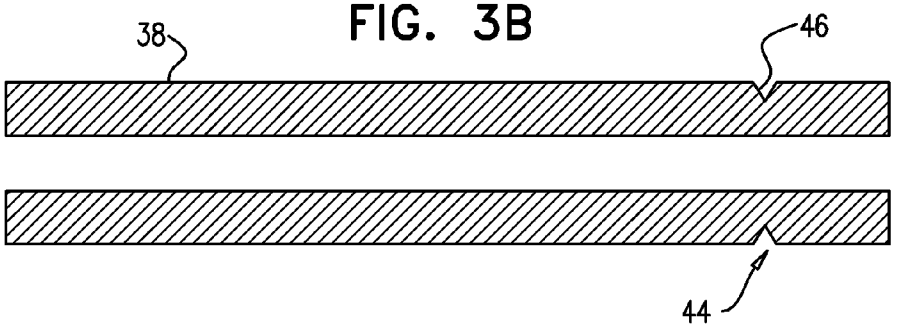


FIG. 3C

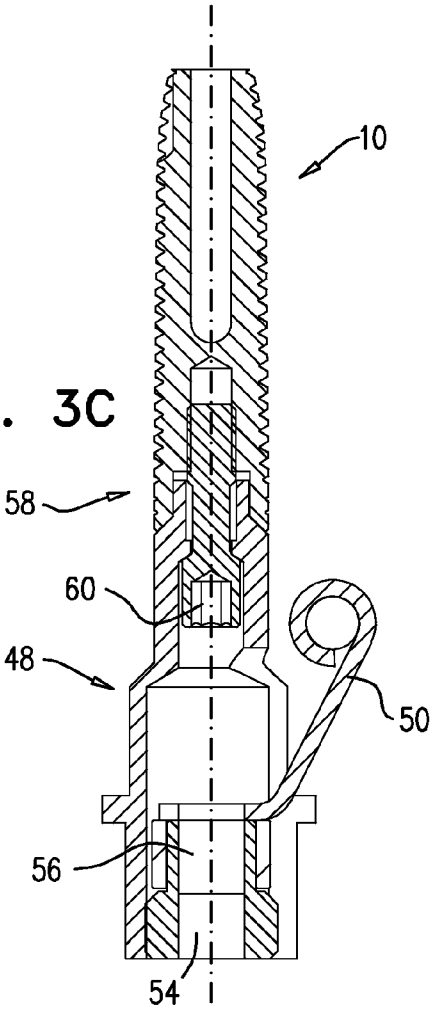
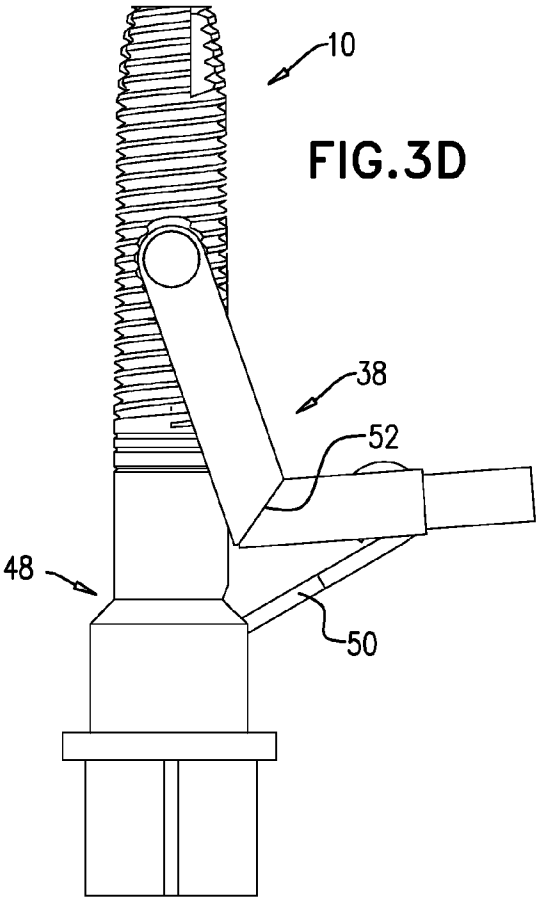
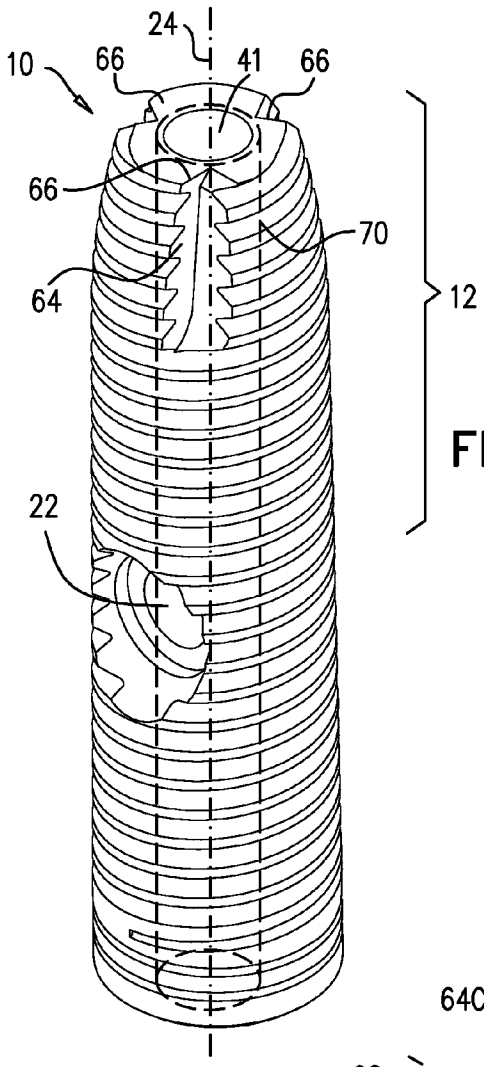


FIG.3D




24
10
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41
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64
12
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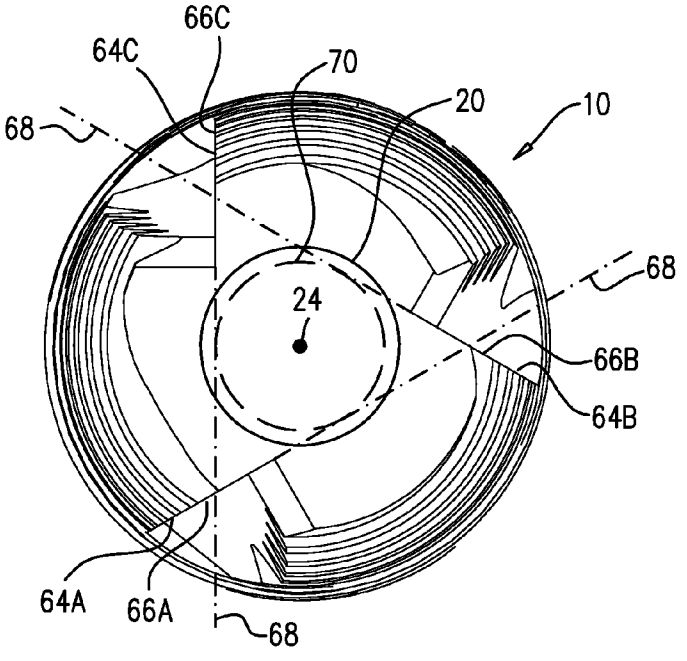
FIG. 4A


66C
64C
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68
20
10
68
24
66B
64B
64A
66A
68

FIG. 4B

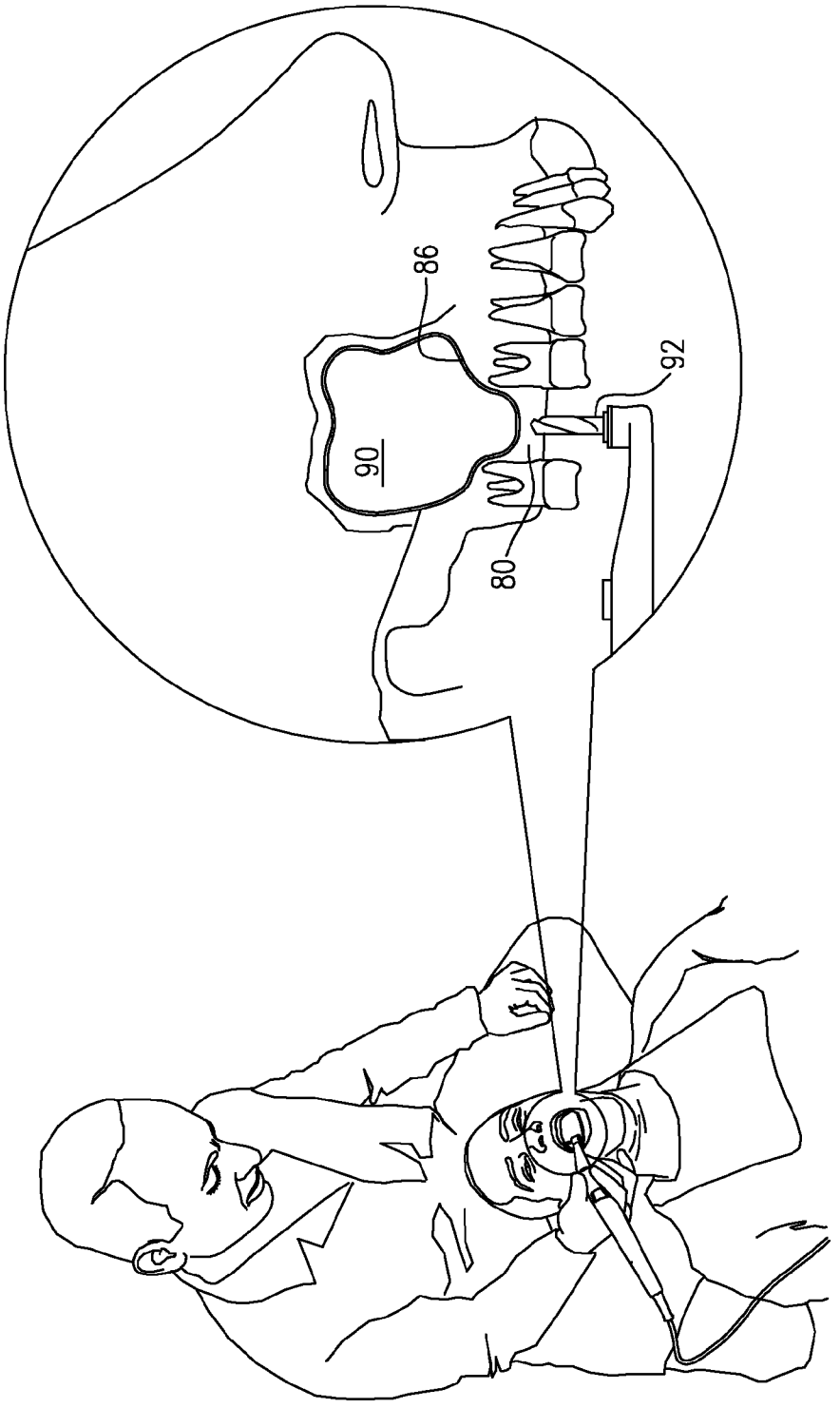


FIG. 5A

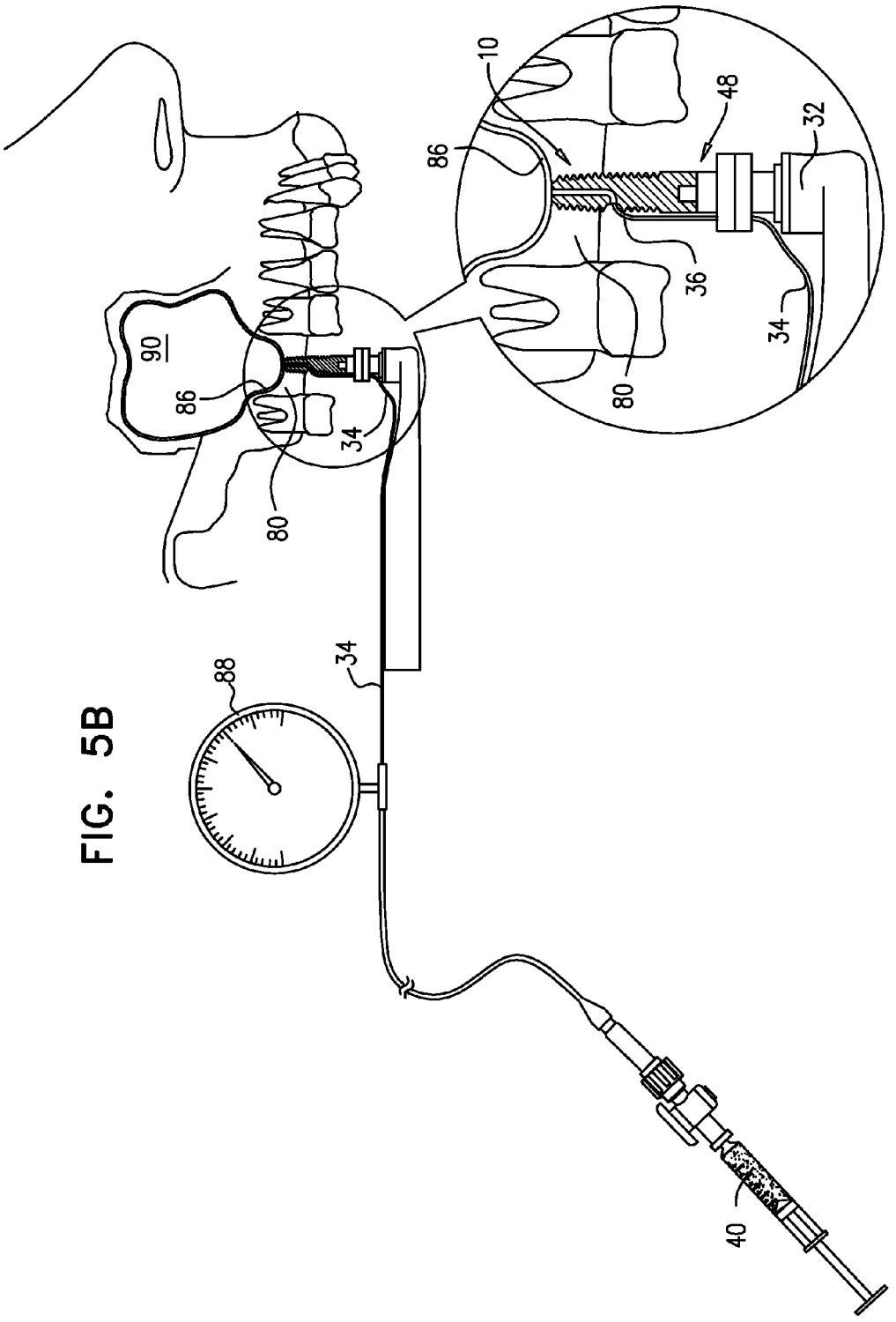


FIG. 5B

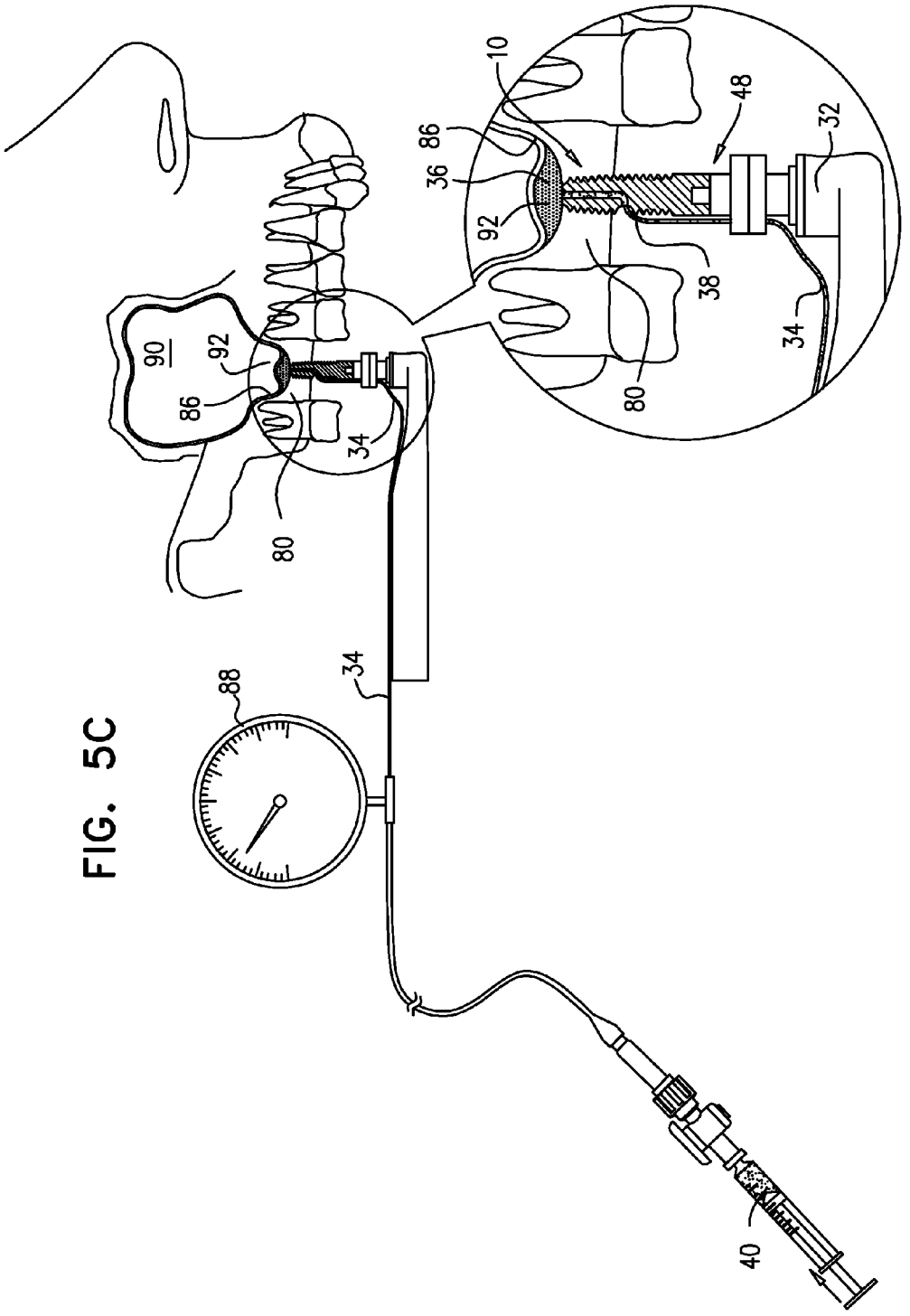


FIG. 5C

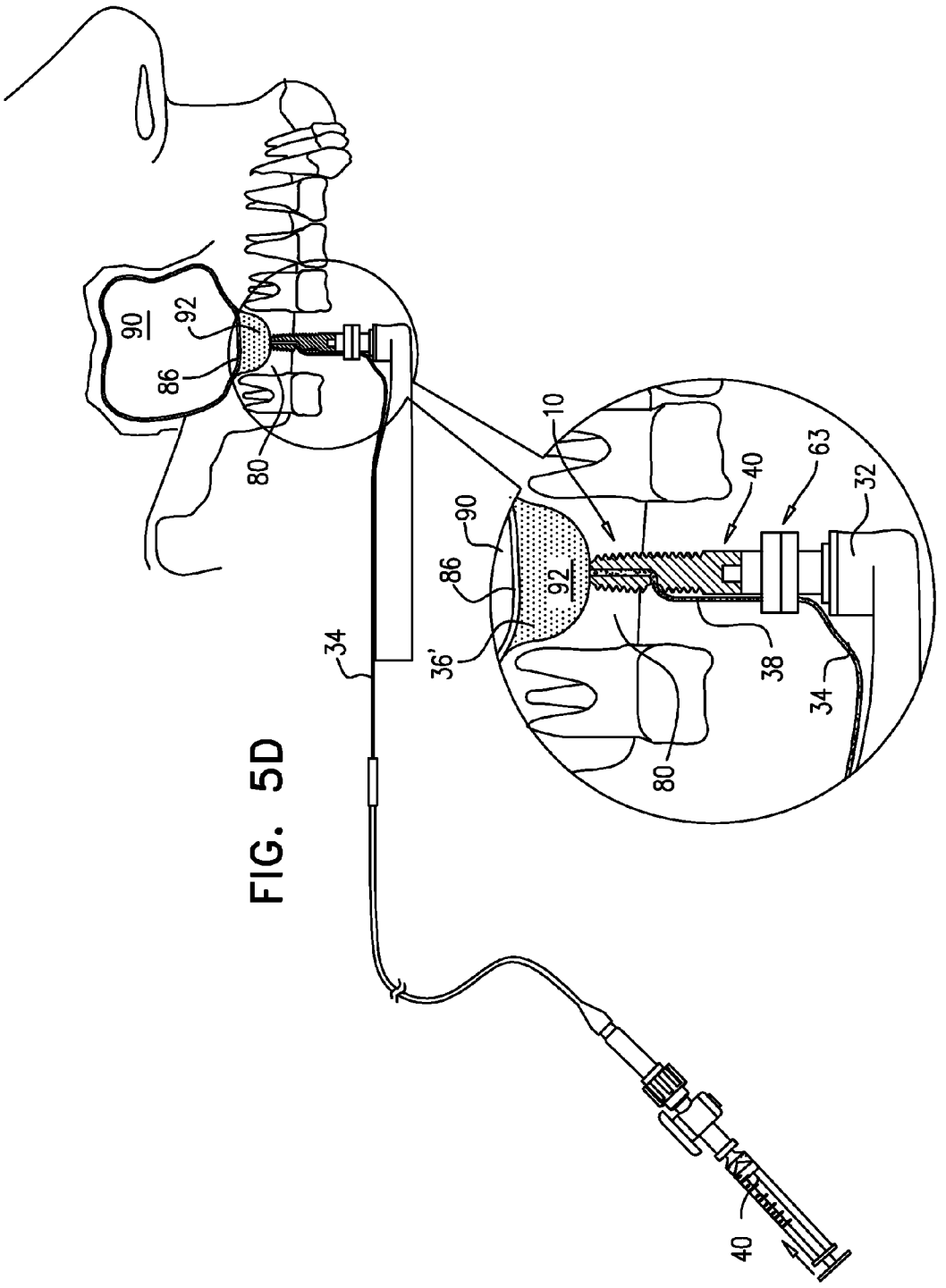


FIG. 5D

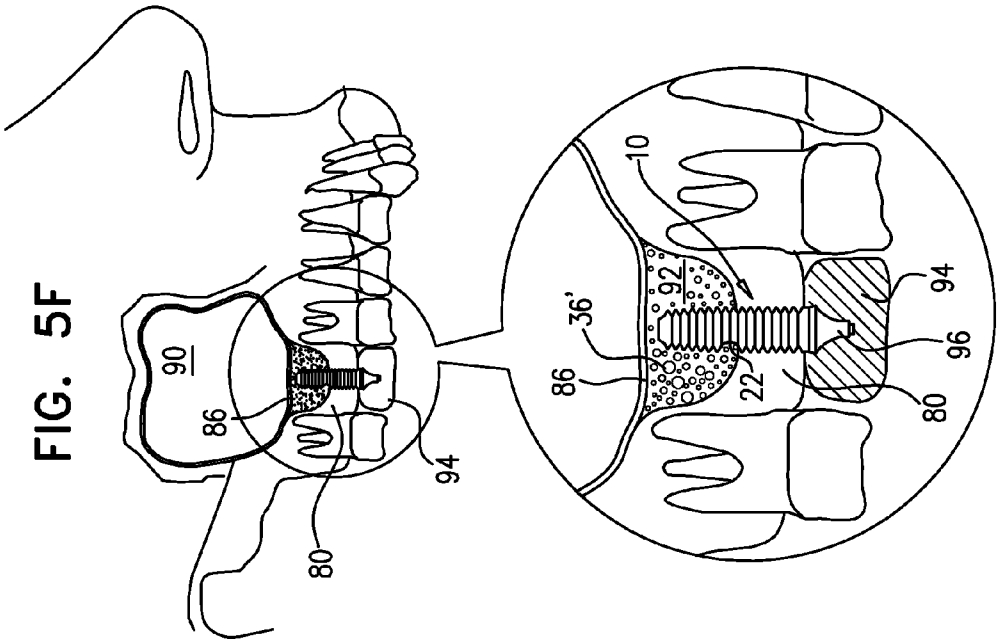


FIG. 5F

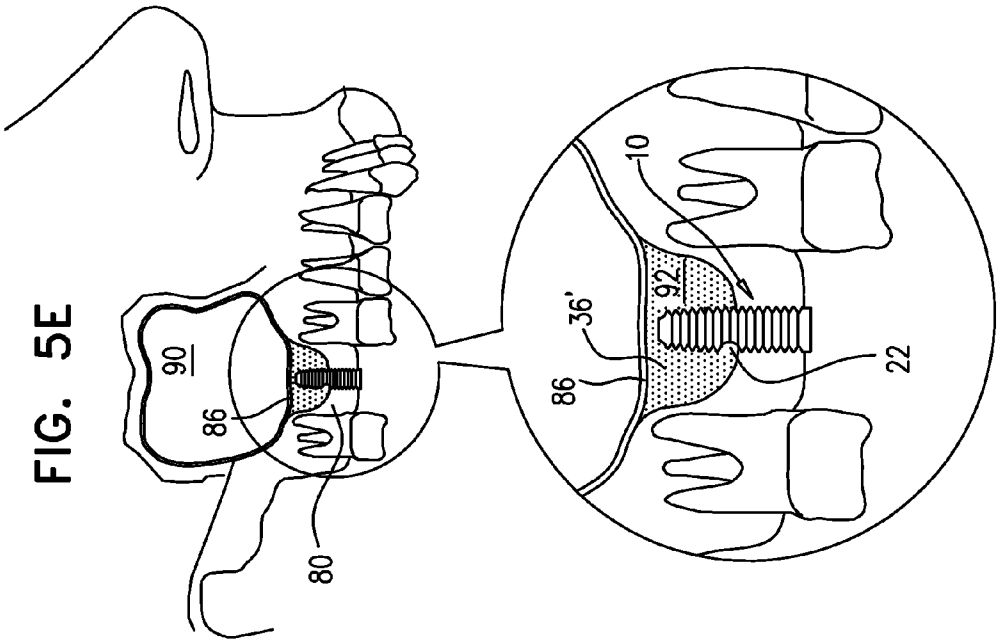


FIG. 5E

FIG. 6A

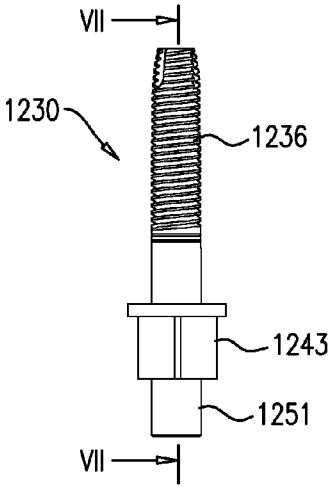


FIG. 6B

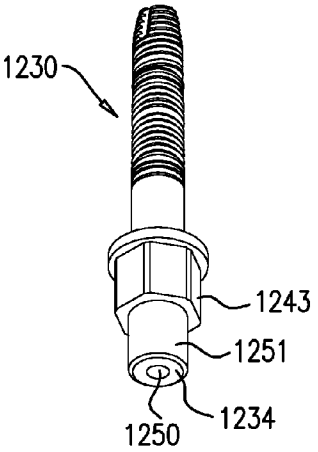


FIG. 6C

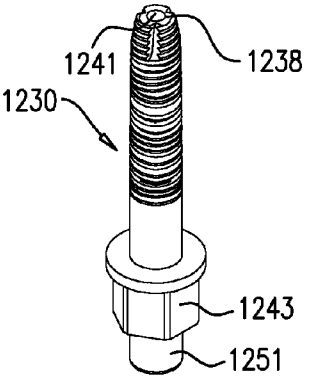


FIG. 7

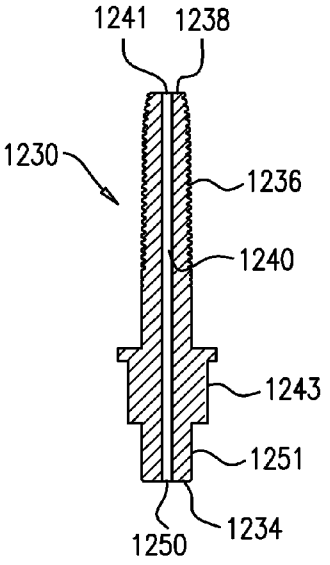


FIG. 8

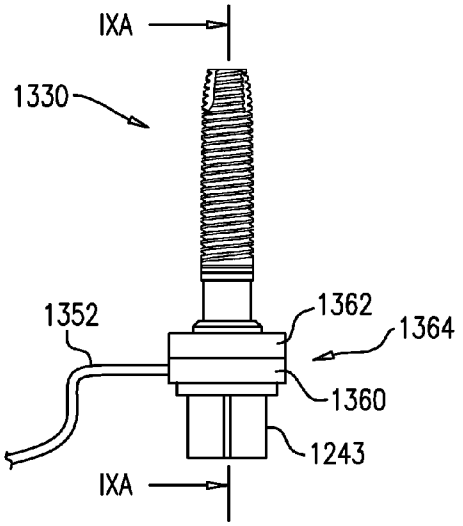


FIG. 9A

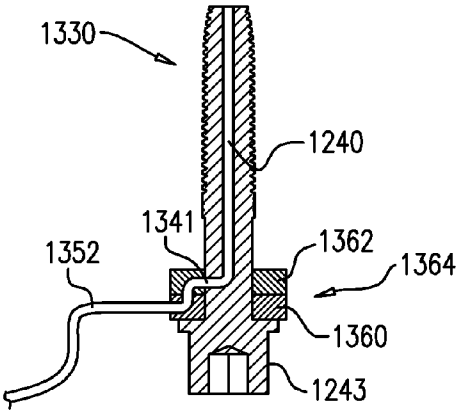
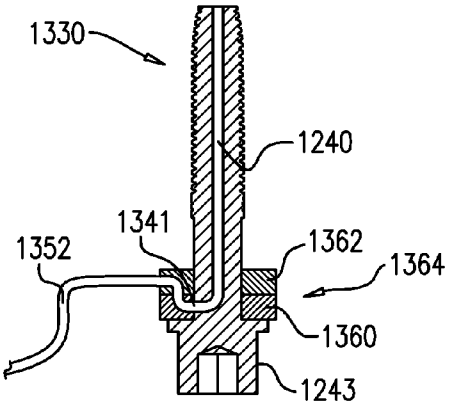


FIG. 9B



IMPLANT SYSTEMS WITH SWIVEL JOINTS FOR SINUS LIFT AND BONE AUGMENTATION

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation of U.S. application Ser. No. 12/661,795, filed Mar. 24, 2010, which is a Continuation-in-Part of: (a) U.S. application Ser. No. 12/240,353, filed Sep. 29, 2008, entitled "Sinus lift implant," to Better et al., now U.S. Pat. No. 7,934,929, (b) U.S. application Ser. No. 12/485,199, filed Jun. 16, 2009, entitled, "Implants, tools, and methods for sinus lift and lateral ridge augmentation, to Better et al., now U.S. Pat. No. 8,029,284, and (c) International Application No. PCT/IL2009/000931, filed Sep. 29, 2009, entitled, "Implants, tools, and methods for sinus lift and lateral ridge augmentation," to Better et al., which published as PCT Publication WO 2010/035270, all of which are assigned to the assignee of the present application and are incorporated herein by reference in their entirety.

FIELD OF TECHNOLOGY

[0002] The presently disclosed embodiments relate generally to implants and implantation methods, and may involve, for example, minimally-invasive sinus lift implants and implantation methods.

BACKGROUND

[0003] Osseointegrated implants are typically metallic or ceramic screws that may be placed in a bone of a patient for supporting a prosthesis. For example, an osseointegrated implant may include a dental implant for insertion into a jawbone of a patient. Such an implant may support an artificial tooth after the loss of a natural tooth. Replacement of a tooth is often a challenging surgical procedure when the remaining bone has insufficient height to support the implant. For example, replacement of the maxillary teeth is often a challenging surgical procedure when the remaining maxillary bone has insufficient height to support the implant. One surgical technique for augmenting the maxillary bone includes introducing a regenerative material, such as autogenic, allogeneic, xenogeneic, or synthetic bone graft, into the vicinity of the maxillary bone. The regenerative material may form additional bone mass that may integrate with the existing maxillary bone, providing the necessary alveolar height to support the implant.

[0004] Bone augmentation procedures are often surgically difficult to perform, and are associated with complications, including infection of the maxillary sinus. The top of the maxillary alveolar ridge forms the floor of the maxillary sinus, and is covered by a thin membrane known as the Schneiderian or subantral membrane. In one surgical procedure, known as a closed or internal sinus lift or elevation procedure, the surgeon drills a bore through the maxillary alveolar ridge from the oral cavity at the desired location of the implant. The bore penetrates the ridge to below the Schneiderian membrane. The surgeon injects the regenerative material through the bore to below the membrane, forming a cavity defined by the top of the ridge and the bottom of the membrane, which cavity occupies a portion of the space initially occupied by the maxillary sinus.

[0005] To prevent potentially serious complications, the surgeon must be careful not to perforate the Schneiderian membrane. This is often difficult, because of the delicacy of the membrane, and the restricted access afforded by the closed approach.

[0006] Various techniques have been developed to augment bones. One such technique includes a method of lifting a membrane using hydraulic pressure applied by a syringe. A second such technique requires the use of various sinus burs and condensers of increasing width in conjunction with a pliable atraumatic bone grafting mixture and hydraulic pressure from a surgical hand piece. A third technique includes the use of a sleeve to raise the subantral membrane and form a cavity. A filler, such as a bone growth stimulant, may be injected through the sleeve into the cavity. In the process, the sleeve may also cut and/or condense the bone around itself so that the bone may hold an implant. Optionally, the bone growth stimulant may be introduced into the bone surrounding the sleeve. During the injection, the pressure within the sleeve or the cavity may be monitored to detect and prevent the rupture of the subantral membrane.

[0007] Further techniques include the use of surgical tools to cut, crack, and push bone from the sinus floor upward into the sinus cavity in a controlled motion. Once the bony sinus floor is cracked free, a fluid passageway may be pressurized with a sterile fluid at a defined pressure to release and push the sinus membrane upward into the sinus cavity which may create a desired apical cavity for grafting. Alternatively, such tools may provide a passageway for carrying fluid through the shank of the tool. Another technique includes the use of an implant comprising at least one shaft area for anchoring in a bony structure, and at least one opening at the distal end of the shaft area in which the shaft area may have a continuous bore extending from the opening to at least one outlet at the apical end, so that targeted introduction of material at least into the periapical area is possible with a stable anchoring in the bone structure even after implantation. Finally, techniques have been developed which may gradually displace periosteal tissue covering bones. The gap developing between the bone and the displaced periosteal tissue may be filled with bone callus as it is in distraction osteogenesis. The techniques allow formation of bone in distraction osteogenesis without cutting a segment of the bone.

[0008] Although the above techniques may improve the ability to augment a bone, such techniques may be very complex, invasive, and painful. They may require a very long recovery time and result in temporary disfiguration. Also, patients may experience a high risk of complications, including, for example, tearing of the Schneiderian membrane and infection. Further, such techniques may often be practiced only by very experienced specialists in the maxillofacial field.

SUMMARY

[0009] In one exemplary embodiment of the invention, an implant apparatus includes an anchor having a distal implant end and an opposite proximal end. The implant apparatus may further include a channel extending though a portion of the anchor and having an outlet opening in the distal implant end. The channel may also include an inlet opening on a side of the anchor between the distal implant end and the proximal end. Further, the inlet opening, the channel, and the outlet opening may be configured to convey fluid therethrough and the implant may be configured for implantation in a bone such that when fully implanted, the side inlet opening is buried in the bone.

[0010] In another disclosed embodiment, the implant apparatus may further include a channel extending though a portion of the anchor in a generally longitudinal direction of the anchor, the channel extending though only a portion of the anchor, from a side inlet opening to the outlet opening on the distal end. The inlet opening, the channel, and the outlet opening may be configured to convey fluid there though.

[0011] In a further disclosed embodiment, an implant method includes drilling a hole in a maxillary bone, and inserting an implant into the hole. Depending on intended use, the implant may be configured such that upon insertion it forms a substantially liquid tight seal between the implant and the maxillary bone. The implant method may further include lifting a Schneiderian membrane by introducing fluid through a channel in the implant such that the fluid contacts the Schneiderian membrane and exerts a force thereon, causing a space between the maxillary bone and the Schneiderian membrane. The implant method may also include draining the fluid from the space via the channel in the implant and conveying bone regenerative material through the channel and into the space.

[0012] For some applications, the implant system comprises a swivel joint having proximal and distal joint portions, which define proximal and distal joint ports, respectively. The joint is arranged so as to define a fluid path from the proximal joint port to the distal joint port via the proximal and distal joint portions. The proximal and distal joint portions are arranged to be rotatable with respect to one another such that the fluid path is preserved during rotation. The proximal end of the delivery tube is coupled to the distal joint port, and a supply tube, which is coupled to a source of fluid, is coupled to the proximal joint port, such that the delivery tube and the supply tube are in fluid communication with one another via the swivel joint.

[0013] There is still further provided, apparatus including:

[0014] a dental implant having a distal implant portion that extends from a distal implant end along up to 50% of a longitudinal length of the implant, the implant shaped so as to define a lumen through the implant, which lumen has at least one distal opening through a distal external surface of the distal implant portion; and

[0015] a swivel joint having first and second joint portions defining first and second joint ports, respectively, the swivel joint arranged so as to define a fluid path from the second joint port to the first joint port via the second and first joint portions, which are arranged to be rotatable with respect to one another such that the fluid path is preserved during rotation,

[0016] wherein the fluid path through the swivel joint is in fluid communication with the lumen via the first joint port.

[0017] In an embodiment, the first joint portion is positioned distal to the second joint portion. For some applications, the implant is shaped such that the lumen has a lateral opening through a lateral external surface of the dental implant, and the apparatus further includes a delivery tube having (a) a proximal tube end that is coupled to the first joint port, and (b) a distal tube end that is removably coupled to the implant such that the delivery tube is in fluid communication with the lumen via the lateral opening when the delivery tube is coupled to the implant.

[0018] In an embodiment, the first joint portion is positioned proximal to the second joint portion.

[0019] For some applications, the apparatus further includes an applicator, which is removably coupled to a proximal implant end of the dental implant, and the swivel joint defines a bore therethrough, in which at least a portion of the applicator is positioned.

[0020] For some applications, the implant is shaped such that the lumen is open to a proximal end of the dental implant through a proximal opening of the implant.

[0021] For some applications, the first joint port is positioned on a surface of the first joint portion facing the dental implant, and a proximal end of the lumen has a lateral opening through a lateral external surface of the implant, which lateral opening is in fluid communication with the first joint port.

[0022] For some applications, the longitudinal length is less than 20 mm, and the implant has a greatest diameter of less than 10 mm.

[0023] There is further provided, in accordance with an embodiment of the present invention, apparatus including:

[0024] a dental implement having a distal portion that extends from a distal end of the implement, the implement shaped so as to define a lumen through the implement, which lumen has at least one distal opening through a distal external surface of the distal portion, and at least a portion of a lateral external surface of the implement is shaped so as to define a cutting surface; and

[0025] a swivel joint having first and second joint portions defining first and second joint ports, respectively, the swivel joint arranged so as to define a fluid path from (a) the lumen, to (b) the first joint port, to (c) the first joint portion, to (d) the second joint portion, to (e) the second joint port, and the first and second joint portions are arranged to be rotatable with respect to one another such that the fluid path is preserved during rotation.

[0026] In an embodiment, the dental implement includes a dental osteotome.

[0027] In an embodiment, the dental implement includes a dental drilling element.

[0028] For some applications, the first joint portion is positioned distal to the second joint portion. Alternatively, the first joint portion is positioned proximal to the second joint portion.

[0029] For some applications, the first joint port is positioned on a surface of the first joint portion facing the dental implement, and a proximal end of the lumen has a lateral opening through the lateral external surface of the implement, which lateral opening is in fluid communication with the first joint port.

[0030] For some applications, a proximal end of the lumen has a lateral opening through the lateral external surface of the implement, and the swivel joint further includes a delivery tube that couples the lateral opening to the first joint port in fluid communication.

[0031] The drawings and detailed description which follow contain numerous alternative examples consistent with the invention. A summary of every feature disclosed is beyond the object of this summary section. For a more detailed description of exemplary aspects of the invention, reference should be made to the drawings, detailed description, and claims, which are incorporated into this summary by reference.

[0032] It is to be understood that the forgoing summary addresses only a few exemplary aspects of the invention, and that both the foregoing general description and the following detailed description are exemplary and explanatory only and are not restrictive of the invention, as claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0033] FIG. **1**A provides a diagrammatic representation of an anchor in accordance with an exemplary disclosed embodiment.

[0034] FIG. **1**B provides a diagrammatic representation of an anchor in accordance with another exemplary disclosed embodiment.

[0035] FIG. **1**C provides a diagrammatic representation of an anchor in accordance with another exemplary disclosed embodiment.

[0036] FIG. **1**D provides a diagrammatic representation of an anchor in accordance with another exemplary disclosed embodiment.

[0037] FIG. **2** provides a diagrammatic representation of an exemplary implant apparatus/system.

[0038] FIG. **3**A provides a diagrammatic representation of an exemplary anchor including a delivery tube and applicator. FIG. **3**B a diagrammatic representation of an alternate exemplary delivery tube.

[0039] FIGS. **3**C and **3**D are diagrammatic representations of alternate views of the structure shown in FIG. **3**A.

[0040] FIG. **4**A provides a perspective view of the exemplary anchor of FIG. **1**A.

[0041] FIG. **4**B provides a top view of the exemplary anchor of FIG. **1**A.

[0042] FIGS. **5**A-**5**F represent an exemplary implantation method.

[0043] FIGS. **6**A-C and **7** are schematic illustrations of a liquid osteotome, in accordance with an embodiment of the present invention.

[0044] FIGS. **8** and **9**A-B are schematic illustrations of another liquid osteotome, in accordance with an embodiment of the present invention.

DESCRIPTION OF EXEMPLARY EMBODIMENTS

[0045] Reference will now be made in detail to exemplary embodiments of the invention, examples of which are illustrated in the accompanying drawings. Wherever possible, the same reference numbers will be used throughout the drawings to refer to the same or like parts.

[0046] FIG. **1**A illustrates an exemplary anchor **10** in accordance with one disclosed embodiment. Anchor **10** may have an elongated shape with a distal implant end **12** and opposite proximal end **14**. At least a portion of anchor **10** may be appropriately configured for insertion into a bone of a patient. While the bone in which anchor **10** may be inserted may include any human or animal bone, for purposes of discussion only, various anchors are discussed herein for use in human jaw or maxillary bones. It is to be understood that this exemplary description is not intended to limit the invention in its broadest sense. While anchor dimensions and shapes may be a function of intended use, and while the invention in its broadest sense is not limited to particular dimensions and shapes, exemplary anchors in accordance with embodiments of the invention may include cylindrical, tapered, and/or conical shapes, and may include structures having, for example, circular or oval cross-sections. Exemplary anchors in accordance with embodiments of the invention may have a greatest diameter, for example, of between about 2 mm and about 7 mm, and may be provided in a variety of longitudinal lengths. In certain embodiments these anchors may have longitudinal lengths of, e.g., between about 7 mm and about 18 mm. More particularly, such anchors may have longitudinal lengths of, e.g., between about 12 and about 16 mm, or even more particularly of about 15 mm. For exemplary purposes only, anchor **10** may have a longitudinal length of about 14 mm, about 15.5 mm, or about 18 mm, or other lengths between about 14 mm and 18 mm. For some applications, anchor **10** may have a longitudinal length of less than about 20 mm and a greatest diameter of less than about 10 mm. The diameter of anchor **10** may be substantially constant or may vary along its longitudinal length. Anchor **10** may be constructed of any biocompatible material of sufficient strength and durability to withstand insertion into a bone of a patient. By way of example only, anchor **10** may be made of a metal such as titanium or stainless steel, a composite, a plastic, a synthetic, or a ceramic, such as a zirconia (zirconium dioxide) ceramic.

[0047] Depending on the intended application, anchor **10** may include external threads **16** for permitting the anchor to be screwed into bone. Anchor **10** may further include tapping and milling elements **64** and **66**, respectively, as discussed later in greater detail with reference to FIGS. **4**A-**4**B.

[0048] Proximal end **14** of anchor **10** may be configured to permit a prosthesis to be connected thereto. For example, when anchor **10** is configured for insertion in a maxillary or jaw bone, proximal end **14** may be configured to support a prosthetic tooth. For other uses, differing prosthetics and other attachments may be connectable to proximal end **14** via mechanical, magnetic, or adhesive connection. Such connecting features may include, for example, internal hexagonal connections, external hexagonal connections, other anti-rotational connections, external screw threads, internal screw threads, lock nut constructions, friction fittings, bayonet type mounts, pin connectors, eyelets, or any other structure that permits secure mechanical connection to anchor **10**. Alternatively, a magnet may be implanted in anchor **10** or the anchor may provide a connection surface to which a structure may be banded, clamped or adhered. It is to be understood that the invention is not limited to anchors **10** with particular connecting features. Rather, if a connecting feature is desired in accordance with an embodiment of the invention, the details of that feature may be chosen to fit the intended application.

[0049] In accordance with one embodiment of the invention there may also be provided a channel extending through a portion of the anchor. As illustrated in FIG. **1**A, for example, a channel **18** may extend from an inlet opening **22** in a side of anchor **10**, through at least a portion of anchor **10**, to an outlet opening **20** on distal implant end **12**. Alternatively, by way of example only, channel **18** may terminate at distal implant end **12** in a plurality of outlet openings **20**, as represented in by the exemplary embodiment of FIG. **1**B. Channel **18** may be configured so as to convey fluid from inlet opening **22** to outlet opening **20**.

[0050] Channel **18** may be formed so as to be coaxial with a central axis **24** of anchor **10**. Alternatively, channel **18** may be formed so as to be offset from central axis **24**. Channel **18** may be configured in any cross-sectional shape or combination of shapes capable of conveying fluid therethrough. Thus, by way of non-limiting example, channel **18** may include a cross-section that is circular, square, rectangular, triangular, or any other cross-sectional shape capable of conveying fluid.

[0051] As shown in FIG. **1**A, channel **18** may extend in a generally longitudinal direction of anchor **10**, from distal implant end **12** towards proximal end **14**. Furthermore, inlet opening **22** may be spaced from the proximal-most end of anchor **10**. As such, channel **18** may be configured to extend

through only a portion of anchor **10**, from the side inlet opening **22** to the outlet opening **20** on the distal implant end **12**.

[0052] Reference is made to FIGS. **1**B-D, which are diagrammatic illustrations of additional exemplary configurations of anchor **10**. In the configuration shown in FIG. **1**B, outlet openings **20** of channel **18** may be located on distal implant end **12** at a location other than coincident with a distal-most tip **26** of anchor **10**. For example, outlet openings **20** may include a plurality of outlet openings **20**, and each may be located at a position of within about 3 mm from distal-most tip **26** of anchor **10**, as measured along the outer surface of anchor **10**. While FIG. **1**B shows a plurality of outlet openings **20**, certain embodiments may include only a single outlet opening **20**. In such an embodiment, outlet opening **20** may be located at a position other than coincident with distal-most tip **26**, but within about 3 mm of distal-most tip **26** as measured along the outer surface of anchor **10**.

[0053] As depicted in FIG. **1**C, the distal-most tip **26** of anchor **10** may be configured to include a concave profile. In certain embodiments, a raised edge formed by the perimeter of the concave region may define a sharp cutting surface **28**.

[0054] Alternatively, as shown in FIG. **1**D, the distal-most tip **26** of anchor **10** may be generally flat. Like the embodiment of FIG. **1**C, however, the embodiment represented by FIG. **1**D may also include a sharp cutting surface **28** formed at or near the perimeter edge of distal-most tip **26** of anchor **10**.

[0055] In the configurations shown in FIGS. **1**C and **1**D, outlet opening **20** of channel **18** may include a single outlet opening **20** which may be coincident with distal-most tip **26**. Alternatively, outlet opening **20** may be at a location other than coincident with distal-most tip **26** of anchor **10**, but within about 3 mm from distal-most tip **26** as measured along the outer surface of anchor **10**. Further, outlet opening **20** may include a plurality of outlet openings **20**, and each may be located at a position of within about 3 mm from distal-most tip **26** of anchor **10**, as measured along the outer surface of anchor **10**.

[0056] As noted above, anchor **10** may be configured for implantation into a bone of a patient. Anchor **10** may be configured to assume a partially-implanted orientation and/or a fully implanted orientation. While in the partially implanted orientation, side inlet opening **22** may be configured to protrude from the bone of implantation so as to permit access to channel **18**. Depending on the intended application, anchor **10** may be configured with a length sufficient to pass through a distal-most side of a bone of implantation while side inlet opening **22** protrudes from the proximal-most side of the bone. In this manner, open channel **18** may exist from inlet opening **22** on the proximal-most side of the bone of implantation to outlet opening **20** on the distal-most side of the bone of implantation (see, e.g., FIG. **5**C).

[0057] Anchor **10** may be further constructed such that when in a fully-implanted orientation, side inlet opening **22** may be buried in the bone of implantation to block inlet access to channel **18** (see, e.g., FIG. **5**E). That is, the inlet opening may be located beneath the outer surface of the bone; may be located within a mass of bone augmenting material within the bone or on a side of the bone opposite the side of implantation; or may be exposed on a side of the bone opposite a side of implantation. In one exemplary embodiment, anchor **10** may be configured such that side inlet opening **22** may be located at a depth of at least 1 mm within the bone of a patient when in the fully-implanted orientation. Alternatively, while in the fully-implanted orientation, side inlet opening **22** may be located at a depth of at least about 3 mm within the bone of a patient. In still other embodiments, anchor **10** may be configured such that side inlet opening **22** may be located at a depth of between about 0-3 mm within the bone of a patient. Further still, anchor **10** may be configured for any depth of burial of side inlet opening **22**, depending on the bone for which anchor **10** is constructed and the intended application. In certain embodiments, when anchor **10** is fully inserted into the bone of the patient, side inlet opening **22** of channel **18** may be permanently closed thus blocking access to the interior of the bone of the patient through anchor **10** from the exterior of the bone of the patient thereby reducing the risk of infection.

[0058] In accordance with one embodiment of the invention there may be provided an exemplary apparatus/implant system **30** as shown in FIG. **2**. System **30** may be used during implantation of anchor **10** into a bone of a patient. System **30** may include any appropriate structure configured to aid in the insertion of anchor **10** into the bone of a patient including, for example, any appropriate electrical or mechanical tooling (e.g., a wrench, surgical screwing tool, etc.) which may be attached to proximal end **14** of anchor **10**. The system may further include a connection to a fluid source to supply sufficient fluid such that, upon insertion into the bone of the patient, the fluid may be directed through channel **18** and into the patient. The introduction of fluid may lift a membrane of the patient located on the distal-most surface of the bone in order to create a cavity between the membrane and the bone of the patient. This cavity may remain filled by the fluid, drained and left empty, or drained and filled with a second fluid. The formed cavity and/or the fluid remaining in the cavity, if any, may induce bone growth within the cavity. Such bone growth may aid in supplementing the existing bone of the patient which may thereby improve the ability of a surgeon to insert an anchor into the bone of the patient.

[0059] The apparatus/system **30** may include anchor **10**, as described hereinabove, and a tool, such as a surgical screwing tool **32**. The surgical screwing tool may be attached to anchor **10** via any appropriate intermediate element, such as, for example, an applicator **48** as described hereinbelow with reference to FIG. **3**A. Surgical screwing tool **32** may be configured to attach to proximal end **14** of anchor **10** and may aid in insertion of anchor **10** into the bone of the patient. For example, surgical screwing tool **32** may comprise a conventional manual ratchet wrench, or a conventional drill or motor to which an appropriate drill head is attached, and may be operated at a controlled speed and at controlled torque. Alternatively, any appropriate tool known in the art may be used to advance anchor **10** into the bone of the patient.

[0060] Further, the apparatus/system **30** may include an inlet conduit **34** configured to direct a fluid **36** (labeled in FIGS. **5**B-C) into channel **18** through side inlet opening **22**. An exemplary inlet conduit **34** is shown in FIG. **2**. Inlet conduit **34** may be of any cross-sectional shape, length and/or size capable of conveying fluid **36** from an external source, through side inlet opening **22**, and to channel **18**. Inlet conduit **34** may include a delivery tube **38** in which the distal end of delivery tube **38** may be connected to side inlet opening **22**.

[0061] As shown in FIG. **2**, a distal end of inlet conduit **34** may be connected to a container **40**. Further, container **40** may be configured to store fluid **36** and may be of any shape or size appropriate to hold sufficient quantities of fluid **36** as

may be dictated by the specific application. Alternatively, container **40** may include any commercially available syringe or powered drug delivery device capable of delivering fluid **36** to channel **18** through side inlet opening **22**. As used herein, "fluid" may refer to, by way of non-limiting example, any one of or a combination of saline solution, water, bone growth stimulation factors such as bone morphogenic protein ("BMP"), blood, bone graft, bone regenerative material, bone augmenting material, an allograph, an autogeneous bone graft, a xenograft, or any other flowable biocompatible material. Further, fluid **36** may, for example, comprise a natural material, a synthetic material, or a mixture thereof. For example, fluid **36** may include one of the following commercially available fluid bone graft materials: DBX Paste (MTF), Allomatrix (Wright), Cerament (Bone Support), DynaGraft (Citagenix/ISOTIS), Fisiograft (Ghimas), Grafton DBM Gel (Osteotech), Optium DBM Gel (Lifenet/Depuy J&J), Osteo-Max (Orthfix), PD VitalOs Cemen (VitalOs), or Regenafil® (Exactech).

[0062] After delivery of fluid **36** into the patient through the delivery tube **38**, the surgeon may decouple delivery tube **38** from anchor **10** before further inserting anchor **10** into the bone of the patient to bring side inlet opening **22** into a blocked position, such as entirely within the bone of the patient. Alternatively, the surgeon may advance the anchor **10** into the patient such that side inlet opening **22** is within the formed cavity. Such positioning of side inlet opening **22** may substantially reduce the risk of infection because the only portion of anchor **10** exposed to the oral cavity of the patient is permanently closed.

[0063] In an embodiment of the present invention, implant system **30** comprises a swivel joint **63** having proximal and distal joint portions **59** and **61**, which define proximal and distal joint ports, respectively. Joint **63** is arranged so as to define a fluid path from the proximal joint port to the distal joint port via proximal and distal joint portions **59** and **61**. Proximal and distal joint portions **59** and **61** are arranged to be rotatable with respect to one another such that the fluid path is preserved during rotation. The proximal end of delivery tube **38** is coupled to the distal joint port, and inlet conduit **34** is coupled to the proximal joint port, such that delivery tube **38** and inlet conduit **34** are in fluid communication with one another via swivel joint **63**. Alternatively, joint **63** is arranged so as to define the fluid path from the distal joint port to the proximal joint port via the distal and proximal joint portions, such as described hereinbelow regarding the swivel joint described with reference to FIG. **9**B.

[0064] For some applications, as shown in FIG. **2**, swivel joint **63** defines a bore therethrough, in which at least a portion of an applicator **48** is positioned. The proximal and distal portions of the joint are independently rotatable around the portion of the applicator in the bore. Rotation of a coupling element **43** at the proximal end of the applicator causes corresponding rotation of the distal end of the applicator and implant **10** (also referred to as "anchor **10**" herein). Such rotation of the implant causes corresponding rotation of side inlet opening **22** and delivery tube **38**, which rotates distal joint portion **61** of swivel joint **63**. However, inlet conduit **34** tends to prevent rotation of proximal joint portion **59** of the swivel joint, causing the proximal and distal joint portions to rotate with respect to one another. Alternatively, the applicator may be rotated by grasping it near or at its distal end. Optionally, distal joint portion **61** of swivel joint **63** is fixed to the body of applicator **48**.

[0065] For some applications, channel **18** is open to a proximal implant end **65** rather than the lateral surface of the implant. For these applications, the distal joint port may open to the bore of the swivel joint, and be in fluid communication with channel **18** via a central lumen of the applicator (configuration not shown).

[0066] For some applications in which distal joint portion **61** of swivel joint **63** is fixed to the body of applicator **48**, the implant is rotated by rotating the distal joint portion. For example, an external surface of the distal joint portion may be shaped so as to define a hexagon that is larger than proximal joint portion **59**, and the distal joint portion may be rotated using a hexagonal ratchet wrench.

[0067] In an embodiment of the present invention, system **30** does not comprise applicator **48**. System **30** comprises swivel joint **63**, which, for some applications, is coupled to implant **10** only by delivery tube **38**. To rotate the implant, a head of a wrench or other tool (e.g., a straight hexagonal screwdriver having a length of about 3 to 4 cm, optionally with a knurled handle) is temporarily inserted through the bore of the swivel joint, and coupled to the coupling element of the implant, which may be a hexagonal socket, for example. Alternatively, the swivel joint is removably coupled to the implant, and removed when delivery tube **38** is decoupled from the implant. For some applications in which the swivel joint is removably coupled to the implant, distal joint portion **61** is shaped so as to define a coupling element, such as a hexagonal coupling element, and the implant is rotated by rotating the coupling element using a wrench or hexagonal screwdriver.

[0068] FIGS. **3**A-C provide diagrammatic views of the apparatus/system **30** of FIG. **2**. As depicted in FIG. **3**A, a distal end of delivery tube **38** may be selectively connected to side inlet opening **22** of anchor **10** for directing fluid **36** into channel **18**. Alternatively, a distal end of delivery tube **38** may form an integral connection **42** between the anchor **10** and delivery tube **38**. The integral connection **42** may be configured such that it is to be permanently severed during implantation of anchor **10** in the bone of a subject. Such an integral connection **42** may be formed by bonding delivery tube **38** to side inlet opening **22** such as through known welding processes. The welding of delivery tube **38** to anchor **10** may provide a strong seal that is able to withstand the pressure of fluid **36** travelling therethrough.

[0069] Alternatively or in addition to integral connection **42**, a wall of delivery tube **38** may include a region of weakened strength **44**, as shown in FIG. **3**A. This region of weakened strength **44** may be constructed so as to be thinner than a wall immediately adjacent to the region of weakened strength **44**. Such a construction may ensure that upon application of a breaking torque, delivery tube **38** breaks at the region of weakened strength **44**, thereby decoupling the delivery tube **38** from anchor **10**. By way of example only, the region of weakened strength **44** may be within about 3 mm of the distal-most end of the delivery tube **38**, such as within about 2 mm or within about 1 mm of the distal-most end of the delivery tube **38**. Alternatively, the region of weakened strength **44** may be either less than or greater than 3 mm from the distal-most portion of the delivery tube **38**.

[0070] Alternatively, as shown in FIG. **3**B, the region of weakened strength **44** may include a groove **46** on delivery tube **38**. Groove **46** may be configured so as to define a thinner region of the delivery tube **38**. For example, groove **46** may be V-shaped, such that application of a breaking torque causes a

concentration of force to be applied at the tip of the V, thereby severing delivery tube **38** at groove **46**.

[0071] The region of weakened strength **44** of delivery tube **38** may be configured so that it is sufficiently thin that upon the application of a breaking torque of less than about 50 Newton centimeters (Ncm), delivery tube **38** severs at the region of weakened strength **44**. By way of example only, the region of weakened strength **44** may have a width of less than about 0.1 mm, such as less than about 0.05 mm. Alternatively, the region of weakened strength **44** may have a width greater than about 0.1 mm.

[0072] In addition, the region of weakened strength **44** may be located beneath the outer surface of implant **10**, in a direction toward central axis **24** of implant **10**. With such a construction, any burrs that might result at locations of severance may be recessed from the outer surface of implant **10**, minimizing risk of tissue damage when implant **10** is further advanced into the bone.

[0073] It is to be understood that the region of weakened strength **44** is not limited to the above features as depicted in FIGS. **3**A-**3**B. Rather, it is envisioned that any structure capable of providing a region of weakened strength **44** may be used.

[0074] Delivery tube **38** may include a rigid material, such as a metal. More broadly, delivery tube **38** may include any material capable of severing at a region of weakened strength **44**. Alternatively, delivery tube **38** may be mechanically disconnectable from inlet opening **22**, such as through a friction fit or mechanical connector, enabling disconnection in manners other than severance.

[0075] Implant/apparatus system **30** may further include an applicator **48** which may be configured to sever delivery tube **38** at the region of weakened strength **44** by rotating the distal end of delivery tube **38** with respect to side inlet opening **22**. For example, applicator **48** may be configured to apply a torque to the delivery tube **38** when the distal end of delivery tube **38** is rotated with respect to side inlet opening **22**. For example, applicator **48** may be configured to apply the torque to delivery tube **38** without applying any meaningful torque to anchor **10** itself, and thus, does not dislodge or misalign anchor **10**.

[0076] To facilitate severing, applicator **48** may include a lever arm **50**, as shown in FIGS. **3**C-**3**D. Lever arm **50** may be coupled to delivery tube **38** and configured to rotate the distal end of delivery tube **38** with respect to side inlet opening **22**. For example, delivery tube **38** may be shaped so as to define a bend **52** at between about 5 mm and about 20 mm from the distal-most end of delivery tube **38**, and lever arm **50** may be coupled to delivery tube **38** at a location proximal to bend **52** (FIG. **3**D). In particular, bend **52** may include an angle of between about 85 and about 180 degrees.

[0077] Further, applicator **48** may comprise a rotatable surface **54** accessible from a proximal end of applicator **48**, which is rotatable with respect to a portion of applicator **48**. Rotation of rotatable surface **54** rotates the distal-most end of delivery tube **38** by extending lever arm **50**. For example, rotation of the rotatable surface **54** may distally advance a transfer element **56** that may extend lever arm **50**. In particular, rotatable surface **54** may define an internal hex, e.g., having an internal width of about 2.4 mm (the hex width is the distance between parallel sides of the hexagon). It is to be understood that other configurations are available to sever delivery tube **38** from the side inlet opening **22** and the configuration shown, and all dimensions, are for exemplary purposes only.

[0078] Further, applicator **48** may include a connecting element **58**, which may removably couple applicator **48** to proximal end **14** of anchor **10**. For example, connecting element **58** may include a connecting screw **60**. As such, a head of connecting screw **60** may be accessible through a cavity that passes through rotatable surface **54**, such that the head can be rotated with a screwdriver tool inserted through proximal end of the applicator **48**, in order to decouple applicator **48** from anchor **10**. In certain embodiments, connecting screw **60** may include an internal hex that has an internal width less than that of rotatable surface **54**, e.g., about 1.25 mm. It is to be understood that the dimensions are for exemplary purposes only and the internal width of a hex may be greater or smaller than about 1.25 mm. Further, applicator **48** may be configured such that, in certain embodiments, rotation of rotatable surface **54** may both (a) apply the breaking torque to delivery tube **38** that may sever delivery tube **38** at the region of weakened strength **44**, and (b) rotate connecting screw **60** to decouple applicator **48** from anchor **10**.

[0079] Further, when delivery tube **38** is coupled to anchor **10** prior to severing at the region of weakened strength **44**, a proximal portion **62** of delivery tube **38** may extend alongside anchor **10** such that, as shown in FIG. **3**A, a greatest distance D between central axis **24** of anchor **10** and an external surface of proximal portion **62** of delivery tube **38** furthest from the central axis **24** is less than about 6 mm, such as less than about 5 mm. Such a distance may facilitate placement of anchor **10** and delivery tube **38** between adjacent teeth during an implantation procedure, such as described herein below with reference to FIGS. **5**A-**5**F.

[0080] Alternatively, delivery tube **38** may be configured to sever from anchor **10** by any other appropriate means. For example, a surgeon or other user may sever delivery tube **38** from anchor **10** via any appropriate separate, external tool.

[0081] As mentioned previously, anchor **10** may include structure to facilitate its insertion into a bone of a subject. In particular, anchor **10** may include a self-tapping surface **64**, including, for example, external thread **16** (FIG. **1**A) in a region of the distal implant end **12**. As shown in FIG. **1**A, external thread **16**, may extend at least along a portion of the lateral external surface of anchor **10**. Alternatively, external thread **16** may extend along the entirety of anchor **10**. Screw thread **16** may include a helical geometry or any other suitable geometry known in the industry. During rotation of the anchor **10**, screw thread **16** allows anchor **10** to advance through a bone of a patient.

[0082] In addition to self-tapping surface **64**, as shown in FIGS. **4**A and **4**B, distal implant end **12** may include at least one end mill cutter surface **66** located adjacent outlet opening **20**. End mill cutter surface **66** may be configured to break through bone and/or to grind bone. Alternatively, end mill cutter surface **66** may include a plurality of end mill cutter surfaces **66** which may be located in positions surrounding outlet opening **20** on distal implant end **12** of anchor **10**. For some applications, for example, distal implant end **12** may be shaped so as to define two, three, four, five, or six end mill cutter surfaces **66**. For example, in the configuration shown in FIGS. **4**A and **4**B, end mill cutter surface **66** defines exactly three cutting surfaces **66**A, **66**B, and **66**C, i.e., is tripartite, and self-tapping surface **64** defines exactly three self-tapping surfaces **64**A, **64**B, and **64**C. Surfaces **64** and **66** may be

distributed evenly about a central axis **24** of anchor **10** and offset from central axis **24**. Surfaces **66** may define lines **68**, as shown in FIG. **4**B. Lines **68** may be tangential to a circle **70** having a center which is intersected by central axis **24** of anchor **10**. The circle **70** may or may not have the same radius as outlet opening **20**. Thus, by way of non-limiting example, for applications in which end mill cutter surface **66** defines exactly two cutting surfaces **66**A and **66**B, lines **68** may be parallel to one another; for applications in which the end mill cutter surface **66** defines exactly three cutting surfaces **66**A, **66**B, and **66**C, lines **68** may form a triangle; and, for applications in which the end mill cutter surface **66** defines exactly four cutting surfaces **66**A, **66**B, **66**C, and **66**D, lines **68** may form a square. It is contemplated that other configurations are available and are to be understood as within the scope of this disclosure.

[0083] The end mill cutter surface **66** may create bone fragments and bone dust during insertion of distal implant end **12** into a bone of a patient. Such bone fragments and bone dust may create a protective buffer of milled bone material. This protective buffer may be retained against distal implant end **12** of anchor **10**. Such a configuration may allow the protective buffer of bone material to protect a Schneiderian membrane or periosteal tissue of a patient as the anchor **10** is advanced through the bone. In addition, end mill cutter surface **66** may grind the bone of the ridge, which is generally effective for breaking through bone. As such, distal portion **12** may both engage the lower portion of the bone while at the same time breaking through the upper portion of the bone.

[0084] In accordance with one embodiment of the invention there may be provided a method of implantation of a device in a bone of a subject. For example, the method may include a minimally invasive closed sinus lift surgical procedure for implanting anchor **10** in a bone of a subject. By way of example only, such a procedure may be performed when a patient's maxillary alveolar ridge lacks sufficient bone mass to support a conventional dental implant. While the method is described for exemplary purposes, as used to implant anchor **10** in a jaw or maxillary bone of a subject, the invention in its broadest sense is not so limited. Rather, it may be applied for use in any bone of a subject, whether human or animal.

[0085] A surgeon may begin the procedure by preparing the oral facial region and administering a local anesthetic. Optionally, as shown in FIG. **5**A, the surgeon may initiate an osteotomy in a maxillary alveolar ridge **80** of a patient. Such an osteotomy may be made by initiating a bore in the alveolar ridge **80** with the aid of a dental implant drill, such as a conventional sinus bur **82**. Alternatively, the initial bore may be formed by using any appropriate means to initiate such an opening in the alveolar ridge **80**. Such a preliminary bore may have a diameter of between about 1 mm and about 7 mm, e.g., between about 2 and about 6 mm. It is to be understood that the bore may have any dimensions appropriate, and as such, it may have a diameter smaller than about 1 mm or larger than about 7 mm. Dimensions are provided for exemplary purposes only. Further, the initial bore may leave a residual bone thickness of between about 0.5 and about 5 mm, e.g., between about 1 and about 4 mm, or between about 0.5 and about 2 mm. Again, it is to be understood that the bore may have any dimensions appropriate, and as such, it may leave a residual bone thickness smaller than about 0.5 mm or larger than about 5 mm. Dimensions are provided for exemplary purposes only.

[0086] Optionally, a surgeon may widen the bore using a series of successively wider drill bits, until a desired bore diameter is achieved as determined by the specific application. For example, the largest drill bit may have a diameter of about 3.65 mm for an implant having a diameter of about 4.2 mm, or a diameter of about 4.2 mm for an implant having a diameter of about 5 mm. It is to be understood that alternative dimensions are deemed to be within the scope of the invention and dimensions are provided only for exemplary purposes only. The bore may be measured using any suitable technique known in the art, such as, by way of example only, depth guide, dental probe, CT imaging, x-ray imaging, or depth guide enhanced x-ray imaging, etc. Also, a surgical guide may be used to ensure clearance between the center of the osteotomy and the nearest tooth surface. Optionally, a pre-surgery radiograph (e.g., CT or x-ray) may be performed, in order to enable the surgeon to estimate the height of the residual bone and plan the osteotomy accordingly.

[0087] After drilling the preliminary bore, the surgeon may advance anchor **10** into the bore. The surgeon may advance anchor **10** by any appropriate means, such as, for example, by screwing anchor **10** into ridge **80** using a surgical screwing tool **32**, as shown in FIG. **5**B. Screwing tool **32** may comprise a conventional manual ratchet wrench, or a conventional drill or motor to which an appropriate drill head is attached, and which is operated at a controlled speed and at controlled torque. Alternatively, screwing tool **32** may include a conventional hexagonal tool with a knurled knob, such as a knurled hex screwdriver, and along its axis, a thin rod having a hexagonal head which fits into a female hexagonal socket defined by a proximal end of applicator **48**. Alternatively, any appropriate tool known in the art may be used to advance anchor **10** into ridge **80**.

[0088] While the surgeon screws anchor **10**, container **40** depicted as a syringe, may optionally provide fluid **36** under monitored pressure to distal implant end **12** via inlet conduit **34**, delivery tube **38**, and channel **18**. As mentioned previously, fluid **36** may comprise any biocompatible solution, for example water, saline, or gas such as air. Further, anchor **10** may function as a cork such that it may isolate a distal-most end of the bore from the oral cavity. Such isolation may allow relatively high pressure to develop in fluid **36** distal to anchor **10**, having exited outlet opening **20**, without being released to the oral cavity of a patient. Also, a drop in the pressure may be detected as distal implant end **12** forms an opening through the distal-most portion of ridge **80** to just below a Schneiderian membrane **86** of a patient. Such an advancement of anchor **10** may bring outlet opening **20** into fluid communication with a proximal-most surface of the membrane **86** as shown in FIG. **5**B. Upon detection of the drop, the surgeon may cease advancing anchor **10** such that anchor **10** does not perforate membrane **86**. At this stage in the procedure, distal implant end **12** may not necessarily pass through the proximal-most portion of ridge **80**.

[0089] The drop in pressure may be detected using any appropriate equipment, for example, a separate pressure gauge **88**. Such a gauge may be coupled to inlet conduit **34**, as shown in FIG. **5**B, or directly to the container **40** (configuration not shown), as is known in the art, e.g., the Viceroy™ Inflation Syringe (Merit Medical Systems, Inc., South Jordan, Utah). Alternatively, for applications in which container **40** includes a powered drug delivery device, the drop in pressure may be detected using a pressure gauge **88** integrated into the drug delivery device, as is known in the art (configuration not shown). Further, an output unit (not shown) may generate an output notifying the surgeon of the drop in pressure. The

output may include any signal sufficient to notify the surgeon, for example, an audio or visual signal, etc. Alternatively or additionally, a display may be used to display an indication of a numerical value of the measured pressure.

[0090] In an alternative embodiment, container **40** may include a loss-of-resistance (LOR) syringe, such as known in the epidural art for locating an epidural space. As such, the surgeon may detect a drop in pressure by detecting a loss of resistance as distal implant end **12** forms an opening through the distal-most side of ridge **80** to just below Schneiderian membrane **88**. For exemplary purposes only, the Episure AutoDetect LOR Syringe (Indigo Orb, Inc., Irvine, Calif., USA) and similar devices may be used.

[0091] Alternatively, instead of providing and measuring a pressure of a fluid, after the initial insertion of anchor **10** into the bore, the surgeon may use a periapical radiograph to estimate remaining distance from distal implant end **12** to the proximal side of the membrane **86**. As such, the surgeon may rotate the anchor **10** to penetrate into a sinus **90**, such as by rotating anchor **10** by a number of rotations equal to the remaining distance divided by a constant, e.g., 1.2 mm. The surgeon may perform an additional periapical radiograph to ensure that anchor **10** has penetrated into sinus **90**.

[0092] Alternatively, to the above mentioned pressure monitoring techniques, the surgeon may introduce fluid **36** through anchor **10** without employing a pressure monitoring means.

[0093] As shown in FIG. **5**C, the surgeon may gently lift and separate membrane **86** from distal-most side of ridge **80** into a sinus **90**, by injecting a fluid **36**, for example a biocompatible solution, from container **40** either under or not under controlled pressure via inlet conduit **34**, delivery tube **38**, and channel **18**, so as to form a cavity **92** under the membrane **86** between ridge **80** and the membrane **86** (in FIG. **5**C, the membrane is shown partially raised). As membrane **86** is raised, an output indicative of a numerical value of the measured pressure, and/or a warning output if the measured pressure crosses a threshold value may be generated as appropriate. An increase in the pressure may generally indicate that the membrane **86** is expanding and may perforate.

[0094] Further, the surgeon may inject sufficient fluid **36** into cavity **92** to inflate cavity **92** to a vertical height, for example, of between about 2 and about 20 mm from the distal-most side of ridge **80**, such as between about 2 and about 11 mm, e.g., between about 2 and about 8 mm. Also, a measured volume of fluid **36** is injected in order to achieve the desired cavity height, such as between about 0.5 and about 6 ml of fluid, e.g., between about 1 and about 4 ml, or between about 2 and about 4 ml. It is to be understood that the invention is not limited to a cavity **92** having particular dimensions or volume. Rather, in accordance with one embodiment of the invention, cavity **92** may have any appropriate dimensions and/or volume sufficient to lift membrane **86** as determined by the particular application.

[0095] The fluid **36**, such as water, saline, other liquid, or gas, may be drained from the cavity **92**, and the surgeon may inject a second fluid **36'** into cavity **92**, as shown in FIG. **5**D. This second fluid may include a regenerative material such as, for example, liquid or gel bone graft, blood, or BMP. Fluid **36'** may be injected using any appropriate means. For example, fluid **36'** may be injected using a syringe, an LOR syringe, a powered drug delivery device, or any other known device for injecting fluid. If a separate syringe or device is used to inject the material, the material may be provided via inlet conduit **34**, or via a separate supply tube coupled to proximal joint portion **59** of swivel joint **63**, or coupled to inlet conduit **34** near the applicator. Optionally, as fluid **36'** is injected into cavity **92**, an output indicative of the pressure of fluid **36'** may be generated as discussed hereinabove above.

[0096] The volume of fluid **36** injected into cavity **92** may be measured, at the step of the procedure described hereinabove with reference to FIG. **5**C. Responsive to the measured volume, the surgeon may determine an amount of fluid **36'** to inject into cavity **92** at the step of the procedure described hereinabove with reference to FIG. **5**D. For example, the amount of fluid **36'** may be approximately equal to the volume of injected fluid **36**, or slightly greater or less than the volume of the injected fluid **36**. As a result, waste of fluid **36'** may be minimized, and the likelihood of perforating membrane **86** by injection of fluid **36'** may be reduced.

[0097] Further, the surgeon may use a flexible wire such as a piston (not depicted) to help push the fluid **36'** through inlet conduit **34**, delivery tube **38**, and/or channel **18**. This technique may be helpful when the fluid **36'** is viscous and thus difficult to inject using an ordinary syringe.

[0098] Alternatively, the surgeon may inject fluid **36'**, rather than fluid **36**, to lift membrane **86**, thereby combining the steps of the procedure described hereinabove with reference to FIGS. **5**C and **5**D. In this case, fluid **36'** may constitute any suitable biocompatible liquid or combinations of biocompatible liquids. Alternatively, the surgeon may drain fluid **36** from cavity **92** and, rather than injecting fluid **36'**, may immediately advance anchor **10** though ridge **80**. In such a configuration, anchor **10**, upon further insertion into the ridge, will lift membrane **86** and retain it in an elevated state. Further, instead of draining fluid **36**, the surgeon may maintain fluid **36** in cavity **92**, thus retaining membrane **86** in a lifted state. In such a configuration, subsequent injection of fluid **36'** may not be required, and anchor **10** may be advanced though ridge **80**.

[0099] Thereafter, the surgeon may decouple delivery tube **38** from anchor **10**, and further advance (e.g., by rotating or screwing) anchor **10** into fluid **36'** in cavity **92**, as shown in FIG. **5**E. The surgeon may decouple delivery tube **38** before or while further advancing anchor **10**, and/or by advancing anchor **10** until the tube becomes decoupled because of the rotation. Alternatively, the surgeon may use any means known in the art for decoupling delivery tube **38** from anchor **10**, such as, for example, a separate external tool.

[0100] As shown in FIG. **5**E, the additional advancing of anchor **10** into ridge **80** and fluid **36'** may advance side inlet opening **22** of anchor **10** at least until side inlet opening **22** is positioned entirely within the bore in ridge **80** and/or in fluid **36'** in cavity **92**. Such positioning of anchor **10** may allow side inlet opening **22** and outlet opening **20** of channel **18** to reside entirely within bone and or fluid **36'**. Such a configuration may substantially reduce the risk of infection, because proximal end **14** of anchor **10**, which may otherwise be exposed to the oral cavity or gingival of a patient, may be permanently closed. The surgeon may then decouple applicator **48** from anchor **10**, by any appropriate means in order to expose proximal end **14** of anchor **10** to the oral cavity or gingival of the patient.

[0101] As is known in the art, fluid **36'**, which, for example, can include regenerative material, may induce bone growth in the area of injection. Such bone growth may aid in supplementing the existing ridge **80**. As shown in FIG. **5**F, after bone grows into fluid **36'** and is integrated into ridge **80**, an appli-

ance **94**, such as a crown, may be coupled to anchor **10**, typically using an abutment **96** coupled to anchor **10**, as is known in the art. Alternatively, anchor **10** may include a single-stage transgingival implant/abutment, as is known in the art.

[0102] Reference is now made to FIGS. **6**A-C and **7**, which are schematic illustrations of a liquid osteotome **1230**, in accordance with an embodiment of the present invention. FIGS. **6**A-C are views from respective directions of the osteotome, FIG. **7** is a cross-sectional view taken along line VII-VII of FIG. **6**A.

[0103] In an embodiment of the present invention, osteotome **1230** is used to perform a sinus lift procedure, e.g., a controlled sinus lift procedure, such as described hereinabove with reference to FIGS. **5**A-D. After the Schneiderian membrane has been lifted, and the regenerative material has been injected into the cavity below the membrane, the surgeon removes osteotome **1230** from the ridge. A dental implant, which may be conventional, is inserted into the bore and cavity. Typically, the diameter of the implant is equal to or slightly greater than the diameter of osteotome **1230**.

[0104] In an embodiment of the present invention, osteotome **1230** is used to perform a lateral ridge augmentation. After the periosteal tissue has been delaminated from the bone, and the regenerative material has been injected into the cavity, the surgeon removes osteotome **1230** from the ridge. A dental implant, which may be conventional, is inserted into the bore and cavity. Typically, the diameter of the implant is equal to or slightly greater than the diameter of the portion of osteotome **1230** that defines a cutting surface, as described hereinbelow.

[0105] Osteotome **1230** is shaped so as to define a lumen **1240** therethrough that is open through a distal opening **1241** to a distal portion of the osteotome that extends from a distal osteotome end **1238** of the osteotome along up to 8 mm of a longitudinal length of the osteotome, such as up to 6 mm of the length, up to 4 mm of the length, or up to 2 mm of the length.

[0106] Distal opening **1241** may be located at distal osteotome end **1238**, such as centered on the distal osteotome end, e.g., at a distal tip of distal osteotome end **1238**, or not centered on the distal osteotome end (and thus located at a location other than the distal tip), such as described hereinabove with reference to FIG. **1**B. Alternatively, distal opening (s) **1241** may be located at one or more locations along distal osteotome portion **1248**, including at locations on a lateral surface of the osteotome. For some applications, the lumen is open to the distal end via a plurality of openings **1241**, which for some applications results in a more even distribution of regenerative material in the cavity, and/or permits passage of the regenerative material even if some of the openings should become blocked with bone particles.

[0107] At least a portion of a lateral external surface of osteotome **1230** is shaped as to define a cutting surface, typically a screw thread **1236**. Osteotome **1230** is typically generally cylindrical, tapered, or conic in shape, other than the lumen, and typically comprises a metal such as stainless steel, titanium, or a ceramic. The portion of the osteotome including the cutting surface (e.g., screw thread **1236**) may have a greatest diameter of between about 2 and about 5 mm, e.g., 3.75 mm.

[0108] The proximal end of lumen **1240** is open to a proximal osteotome end **1234** through a proximal opening **1250** of the osteotome. A supply tube (not shown) is coupled to the proximal opening in order to supply fluid and regenerative material to the lumen, as described hereinabove. Typically, the supply tube is inserted into a short channel defined by a proximal-most portion **1251** of the osteotome, which portion may have a length of between 2 and 5 mm, for example.

[0109] The proximal end is shaped so as to define a coupling element **1243**, such as a male coupling element, e.g., a hexagonal head. The surgeon typically uses conventional dental wrenches to engage the coupling element and rotate the osteotome.

[0110] In an embodiment of the present invention, the distal portion of the osteotome is shaped so as to define at least one surface selected from the group consisting of: at least one end mill cutter surface, at least one self-tapping surface, and both the at least one end mill cutter surface and the at least one self-tapping surface, such as described hereinabove for the implant with reference to FIGS. **19**A-B. Unlike conventional end mill and self-tapping surfaces, the end mill cutter and self-tapping surfaces do not extend into a central area of the osteotome that defines lumen **1240**. This confining of the surfaces to the outer area of the osteotome accommodates the distal opening and lumen. For some applications, the end mill and self-tapping surfaces do not extend into a cylindrical area, a central axis of which coincides with a central axis of the osteotome, and which area extends along the entire length of the osteotome. The cylindrical area typically has a diameter of at least 0.3 mm, such as at least 0.5 mm, or at least 1.5 mm. For some applications, the greatest diameter of the osteotome (i.e., the diameter of the osteotome at its widest portion) is no more than 5 mm, such as no more than 4 mm.

[0111] The end mill cutter surface creates bone fragments and bone dust that protects the Schneiderian membrane or periosteal tissue as the osteotome is advanced through the bone. In addition, the end mill cutter surface grinds the bone of the ridge, which is generally effective for breaking through bone.

[0112] For some applications, the end mill cutter surface is shaped so as to define exactly two, exactly three, exactly four, exactly five, or exactly six cutting surfaces, such as described hereinabove for the implant with reference to FIGS. **19**A-B. For example, in the configuration shown in FIGS. **6**A-C and **7**, the end mill cutter surface defines exactly three cutting surfaces, i.e., is tripartite. Typically, the cutting surfaces are distributed evenly about a central axis of the osteotome, offset from the center. Lines respectively defined by the cutting surfaces are typically tangential to a circle having a center which is intersected by the central axis of the osteotome (the circle may or may not have the same radius as the distal opening).

[0113] For some applications, the distal portion of the osteotome is shaped so as to define a conical cross-section that is configured to cause bone condensation, which generally improves bone density.

[0114] Typically, a total length of osteotome **1230** is between 5 and 35 mm, such as between 8 and 28 mm.

[0115] Reference is made to FIGS. **8** and **9**A-B, which are schematic illustrations of a liquid osteotome **1330** that comprises a swivel joint **1364**, in accordance with an embodiment of the present invention. FIG. **9**A is a cross-sectional view taken along line IXA-IXA of FIG. **8**, and FIG. **9**B is a cross-sectional view of another configuration of osteotome **1330**. Other than as described hereinbelow, osteotome **1330** is generally similar in structure and use to osteotome **1230**, described hereinabove with reference to FIGS. **6**A-C and **7**.

Osteotome **1330** is typically used to perform a sinus lift or lateral ridge augmentation, as described hereinabove with reference to FIGS. **6**A-C and **7**.

[0116] Osteotome **1330** comprises a swivel joint **1364** having first and second joint portions, which define first and second joint ports, respectively. For some applications, the first joint portion is a distal joint portion **1362**, and the second joint portion is a proximal joint portion **1360**, as shown in FIG. **9**A. For other application, the first joint portion is proximal joint portion **1360**, and the second joint portion is distal joint portion **1362**, as shown in FIG. **9**B.

[0117] Joint **1364** is arranged so as to define a fluid path from the first joint port to the second joint port via first and second joint portions. The fluid path is thus defined from (a) lumen **1240**, to (b) the first joint port, to (c) the first joint portion, to (d) the second joint portion, to (e) the second joint portion. The joint portions are arranged to be rotatable with respect to one another such that the fluid path is preserved during rotation. Typically, the first joint portion is fixed to the body of osteotome **1330**, while the second joint portion is configured to rotate freely with respect to the body of the osteotome and the first joint portion.

[0118] The proximal end of lumen **1240** is open through a lateral opening **1341** on a lateral surface of the osteotome (rather than through a proximal opening **1250**, as is the case for osteotome **1230**, described hereinabove with reference to FIGS. **6**A-C and **7**). The lateral opening is aligned with the first joint port, such that the lateral opening is in fluid communication with the first joint port, and a fluid path is defined from the lumen to the first joint portion. Alternatively, the swivel joint further comprises a delivery tube, and the swivel joint is configured as described hereinabove with reference to FIG. **2**.

[0119] A supply tube **1352** is coupled to the second joint port, such that lumen **1240** and supply tube **1352** are in fluid communication with one another via swivel joint **1364**.

[0120] Swivel joint **1364** defines a bore therethrough, in which a portion of the body of the osteotome is positioned. The proximal end of the osteotome is shaped so as to define coupling element **1243**, such as a male coupling element, e.g., a hexagonal head. The surgeon typically uses conventional dental wrenches to engage the coupling element and rotate the osteotome, while the second joint port remains generally stationary because it is connected to supply tube **1352**. This configuration thus allows convenient rotation of the osteotome without the need to rotate the supply tube. In addition, osteotome **1340** is generally shorter than osteotome **1240** because osteotome **1340** does not include proximal-most portion **1251**, which is used for coupling the supply tube to osteotome **1240**, as described hereinabove with reference to FIGS. **6**A-C and **7**. Furthermore, osteotome **1340** occupies less space in the patient's mouth than does osteotome **1240**, because there is no need to accommodate the bending radius of a supply tube inserted into proximal-most portion **1251** of osteotome **1240**, as described hereinabove with reference to FIGS. **6**A-C and **7**.

[0121] Typically, a total length of osteotome **1330** is between 5 and 35 mm, such as between 8 and 28 mm.

[0122] In the foregoing Description of Exemplary Embodiments, various features are grouped together in a single embodiment for purposes of streamlining the disclosure. This method of disclosure is not to be interpreted as reflecting an intention that the claimed invention requires more features than are expressly recited in each claim. Rather, as the following claims reflect, inventive aspects lie in less than all features of a single foregoing disclosed embodiment. Thus, the following claims are hereby incorporated into this Detailed Description, with each claim standing on its own as a separate embodiment of the invention.

[0123] Moreover, it will be apparent to those skilled in the art from consideration of the specification and practice of the present disclosure that various modifications and variations can be made to the disclosed apparatuses and methods without departing from the scope of the invention, as claimed. Thus, it is intended that the specification and examples be considered as exemplary only, with a true scope of the present disclosure being indicated by the following claims and their equivalents.

1-29. (canceled)

30. Apparatus comprising:

a dental implant having a distal implant portion that extends from a distal implant end along up to 50% of a longitudinal length of the implant, the implant shaped so as to define a lumen through the implant, which lumen has at least one distal opening through a distal external surface of the distal implant portion; and

a swivel joint having first and second joint portions defining first and second joint ports, respectively, the swivel joint arranged so as to define a fluid path from the second joint port to the first joint port via the second and first joint portions, which are arranged to be rotatable with respect to one another such that the fluid path is preserved during rotation,

wherein the fluid path through the swivel joint is in fluid communication with the lumen via the first joint port.

31. The apparatus according to claim **30**, wherein the first joint portion is positioned distal to the second joint portion.

32. The apparatus according to claim **30**, wherein the first joint portion is positioned proximal to the second joint portion.

33. The apparatus according to claim **30**, further comprising an applicator, which is removably coupled to a proximal implant end of the dental implant, wherein the swivel joint defines a bore therethrough, in which at least a portion of the applicator is positioned.

34. The apparatus according to claim **30**, wherein the implant is shaped such that the lumen is open to a proximal end of the dental implant through a proximal opening of the implant.

35. The apparatus according to claim **30**, wherein the longitudinal length is less than 20 mm, and wherein the implant has a greatest diameter of less than 10 mm.

36. Apparatus comprising:

a dental implement having a distal portion that extends from a distal end of the implement, the implement shaped so as to define a lumen through the implement, which lumen has at least one distal opening through a distal external surface of the distal portion, and wherein at least a portion of a lateral external surface of the implement is shaped so as to define a cutting surface; and

a swivel joint having first and second joint portions defining first and second joint ports, respectively, the swivel joint arranged so as to define a fluid path from (a) the lumen, to (b) the first joint port, to (c) the first joint portion, to (d) the second joint portion, to (e) the second joint port, wherein the first and second joint portions are arranged to be rotatable with respect to one another such that the fluid path is preserved during rotation.

37. The apparatus according to claim **36**, wherein the dental implement comprises a dental osteotome.

38. The apparatus according to claim **36**, wherein the dental implement comprises a dental drilling element.

39. The apparatus according to claim **36**, wherein the first joint portion is positioned distal to the second joint portion.

40. The apparatus according to claim **36**, wherein the first joint portion is positioned proximal to the second joint portion.

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