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(54) **TRANSOSSEOUS BONE PLATE FOR FIBULA FLAP AND DENTAL IMPLANT RECONSTRUCTION**

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(52) **U.S. Cl.**

CPC ***A61B 17/151*** (2013.01); ***A61B 17/1739*** (2013.01); ***A61B 17/8071*** (2013.01)

(57) **ABSTRACT**

A mandible reconstruction and dental implant system includes a first reconstruction template, including a body, a first cutting guide and a second cutting guide, a first plantar plate slot template disposed along the body, the first plantar plate slot template being an opening configured to receive a drill therein, a first bone fastener template disposed along the body, the first bone fastener template being an opening configured to receive the drill therein, and a first implant template disposed along the body and aligned with the first plantar plate slot template, the first implant template being an opening configured to receive a drill therein, an axis through the first implant template being orthogonal to an axis through the first plantar plate slot template; and a reconstruction plate, including a main bracket, and a first plantar plate protruding orthogonally from the main bracket, the first plantar plate including an aperture.

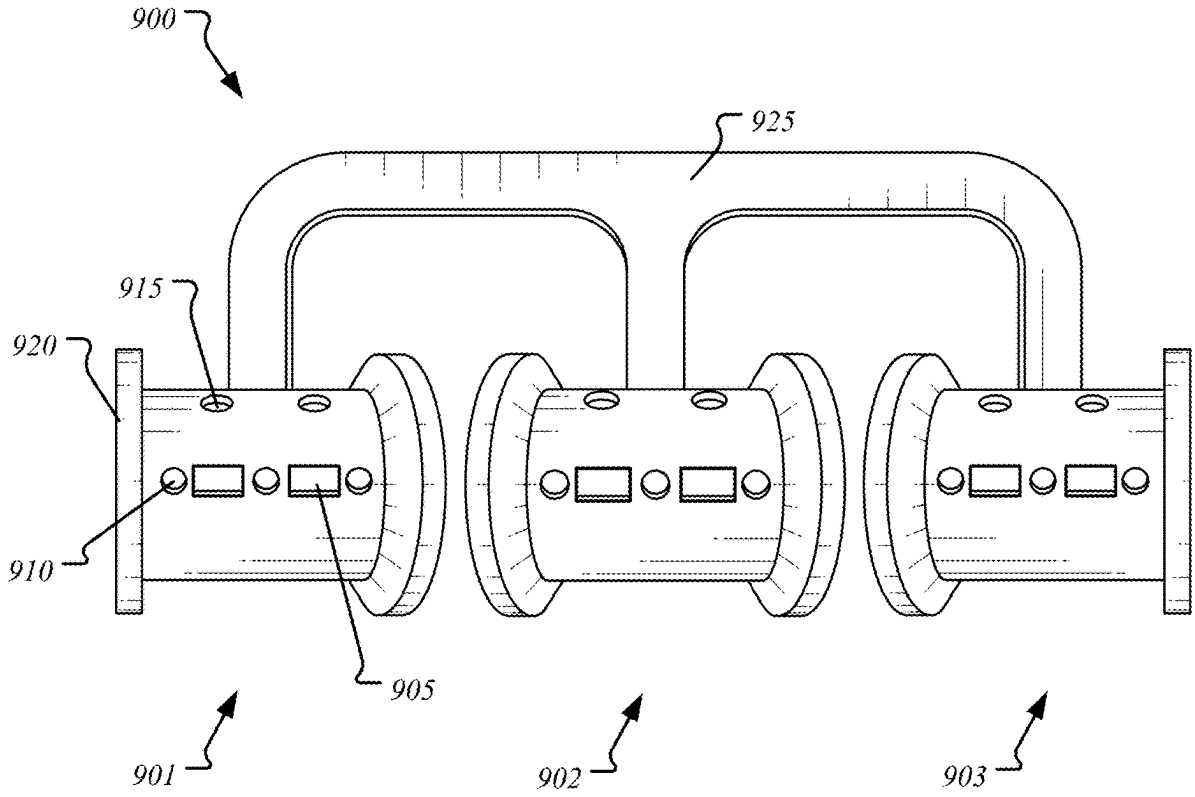
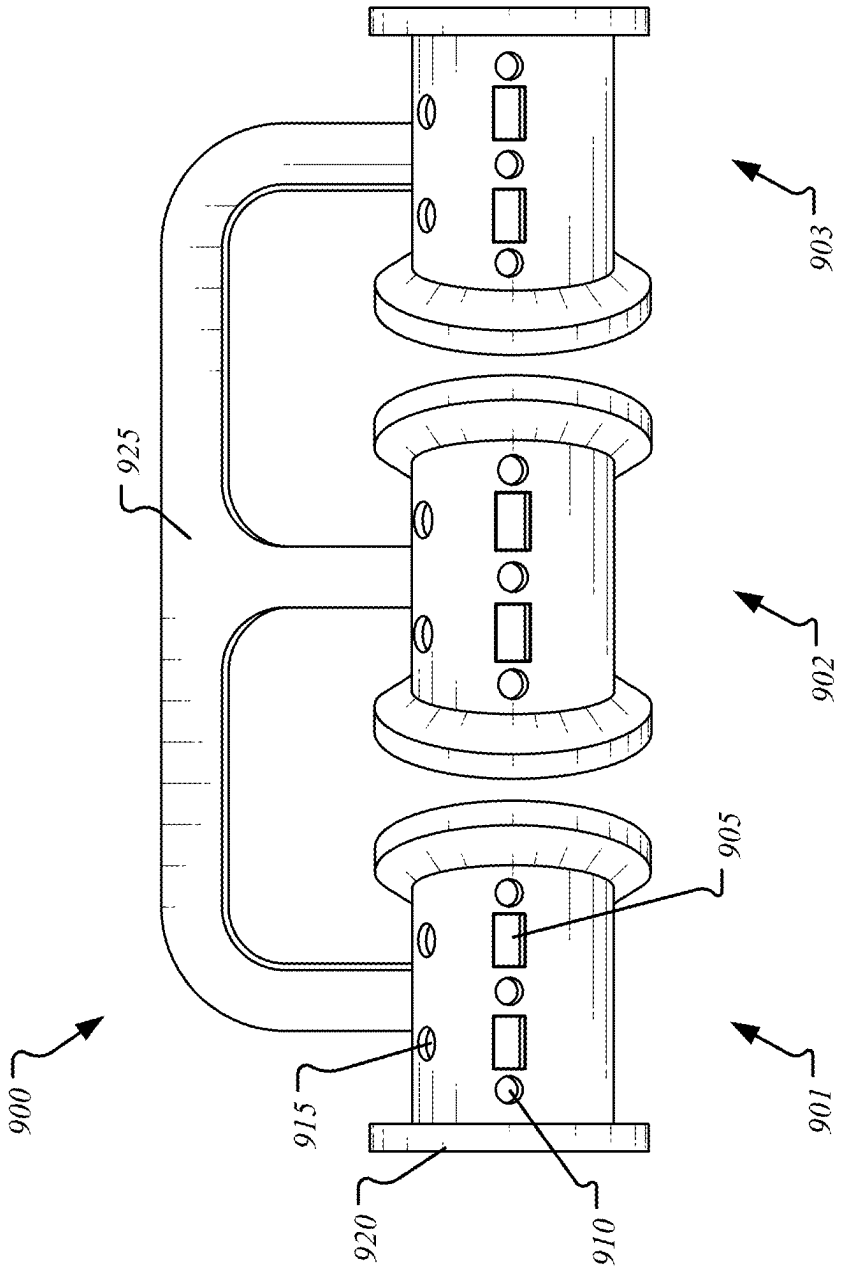


FIG. 1



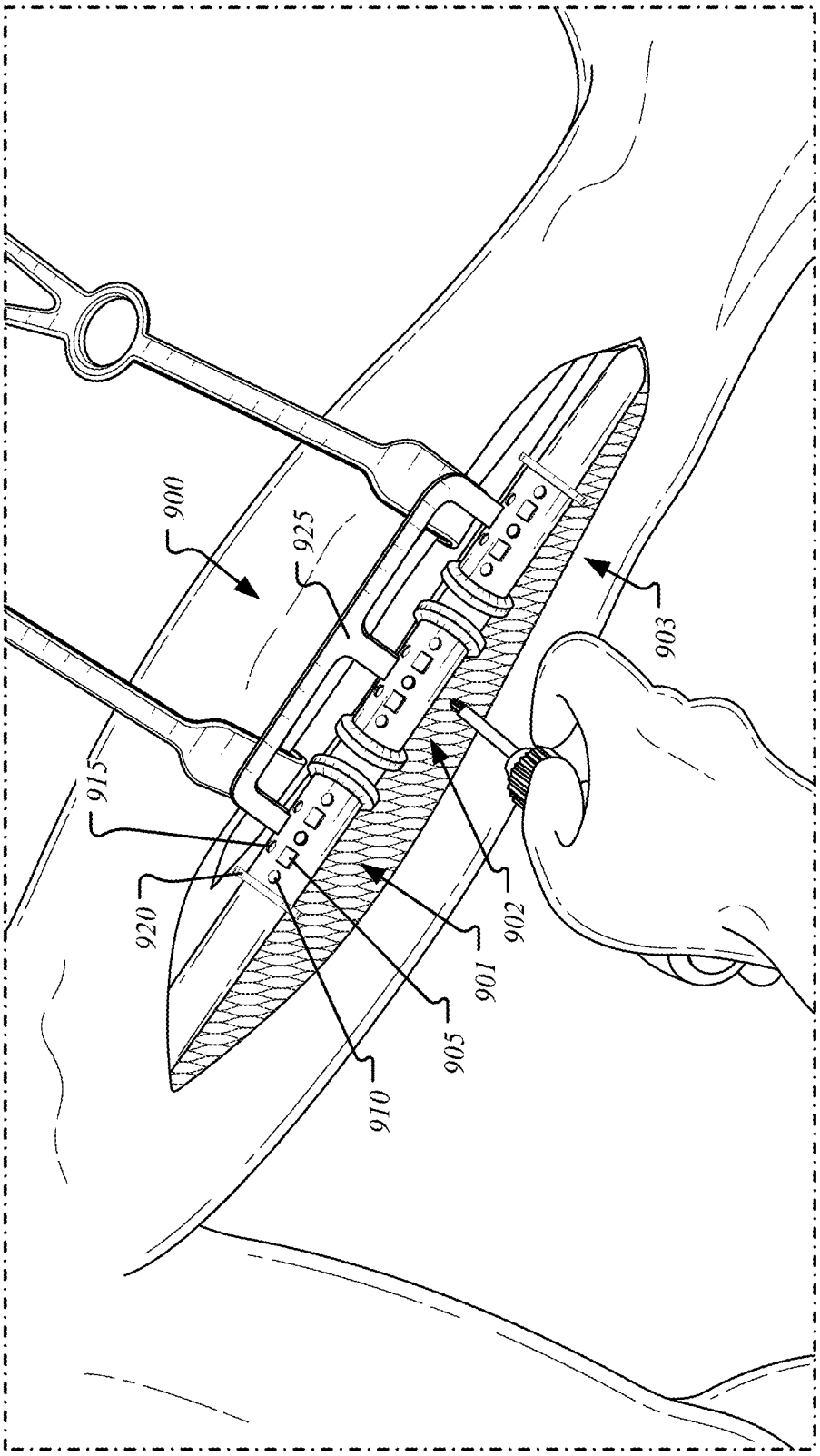


FIG. 2

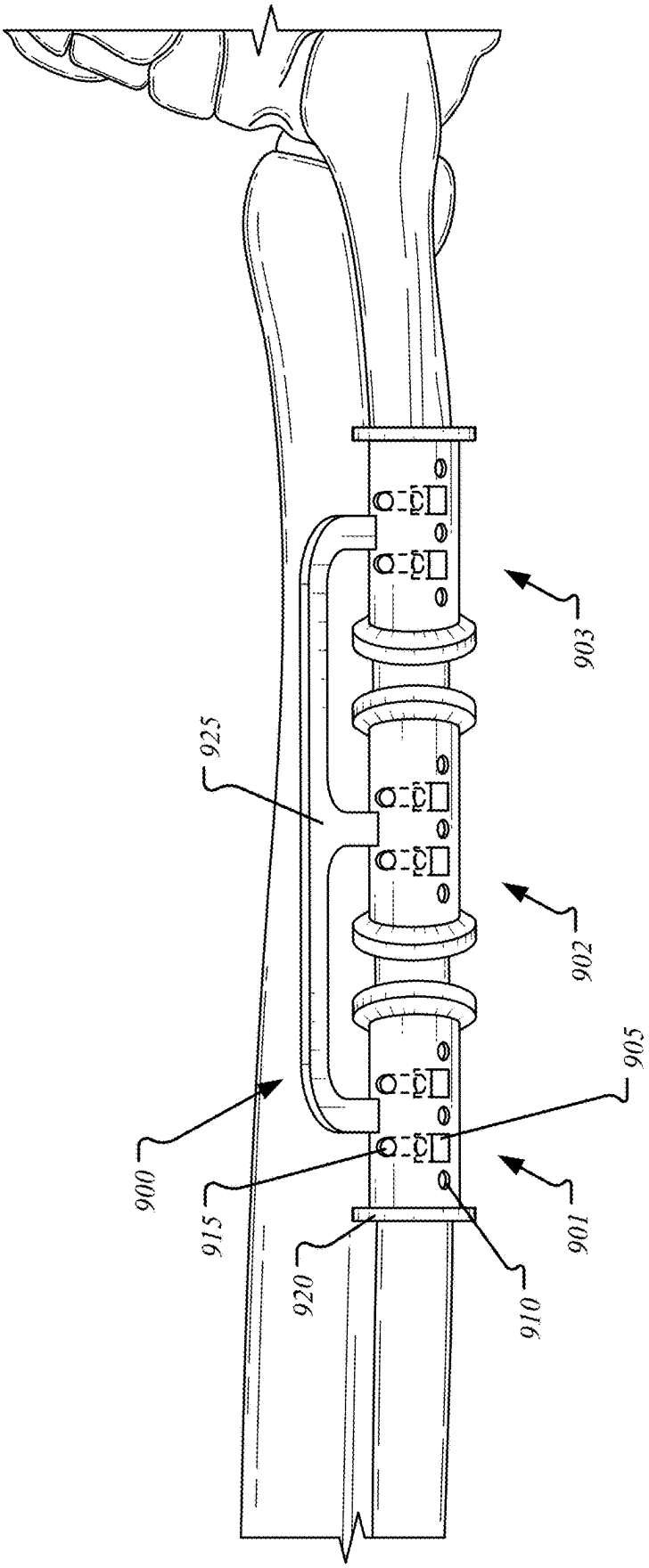


FIG. 3A

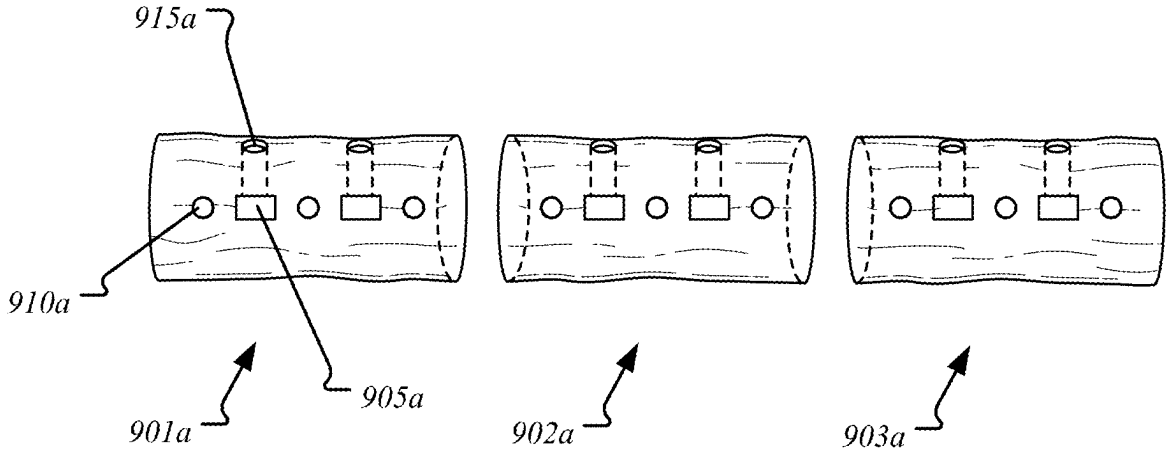


FIG. 3B

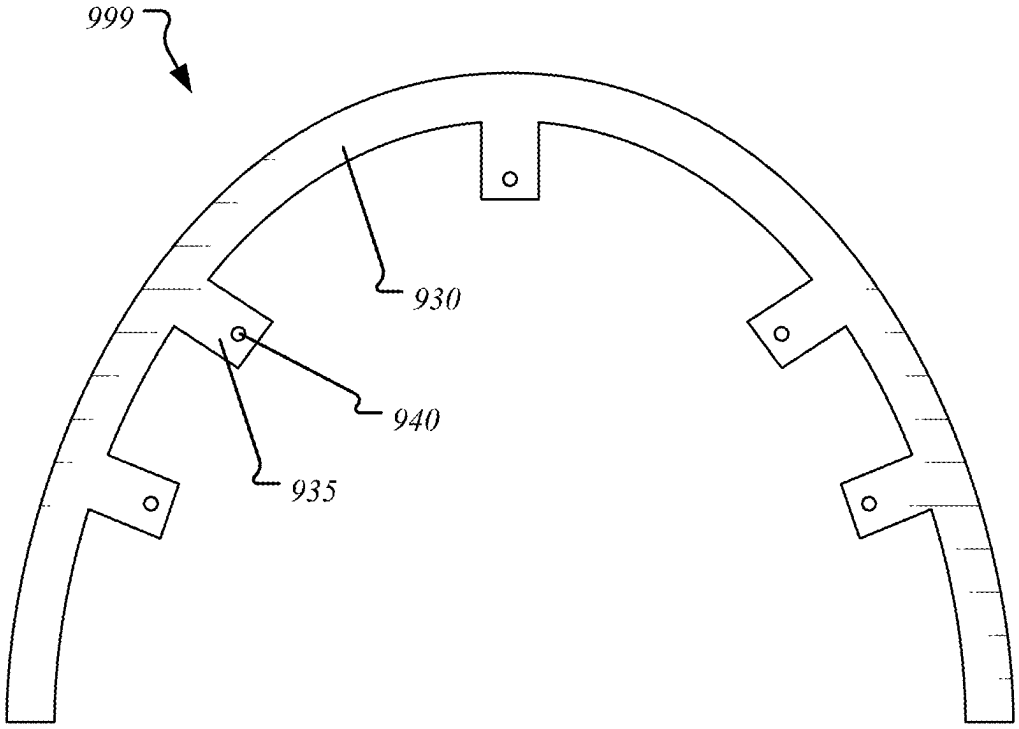


FIG. 3C

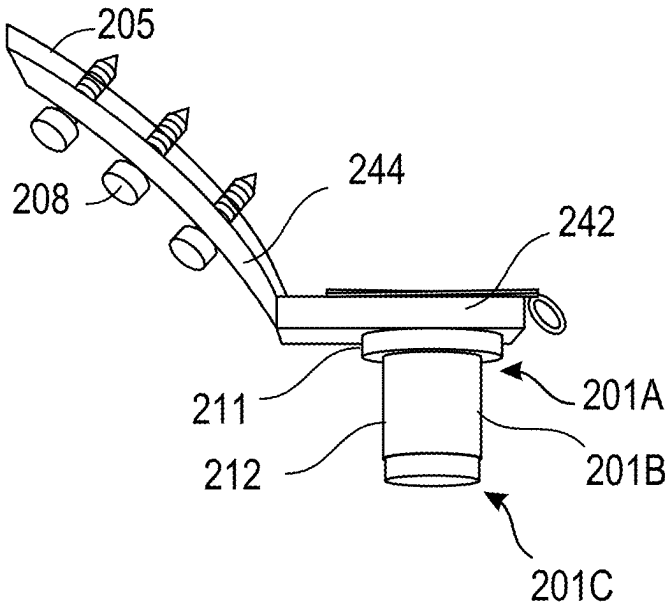


FIG. 3D

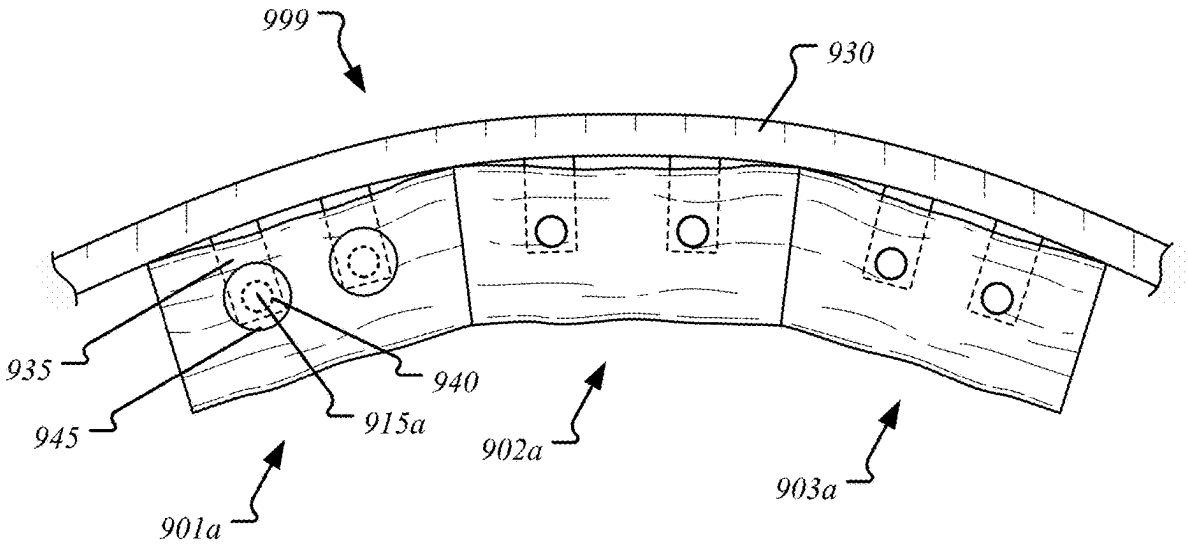


FIG. 4A

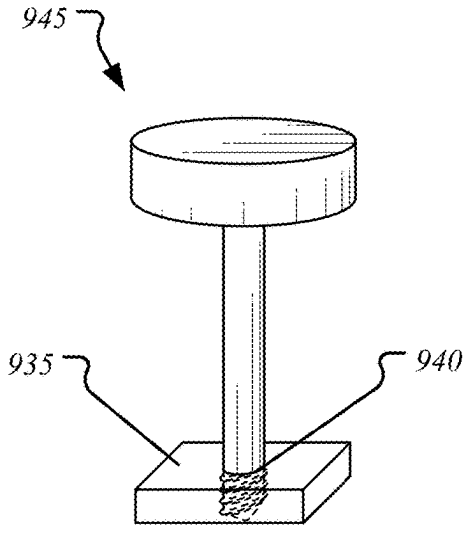


FIG. 4B

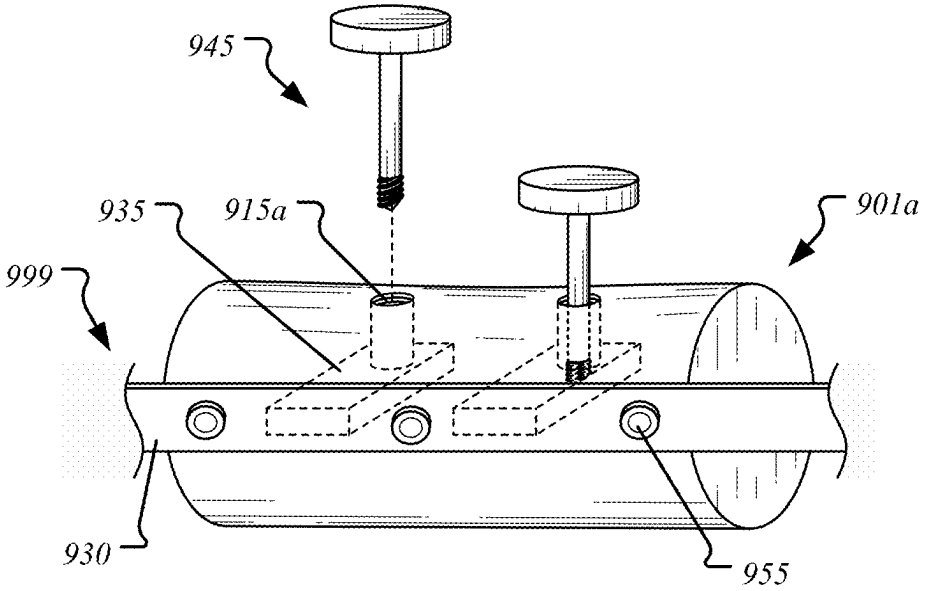


FIG. 4C

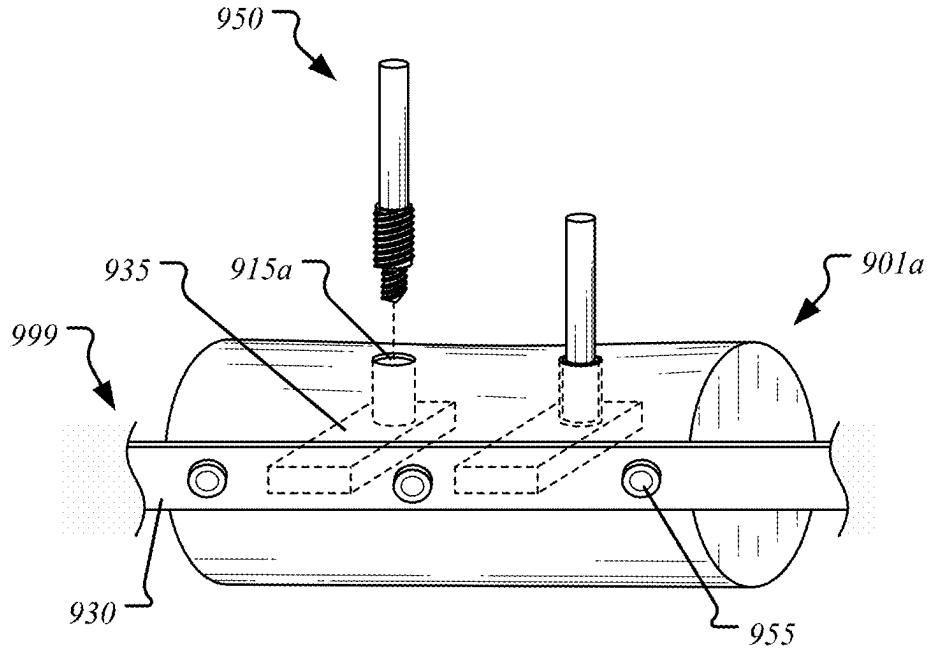
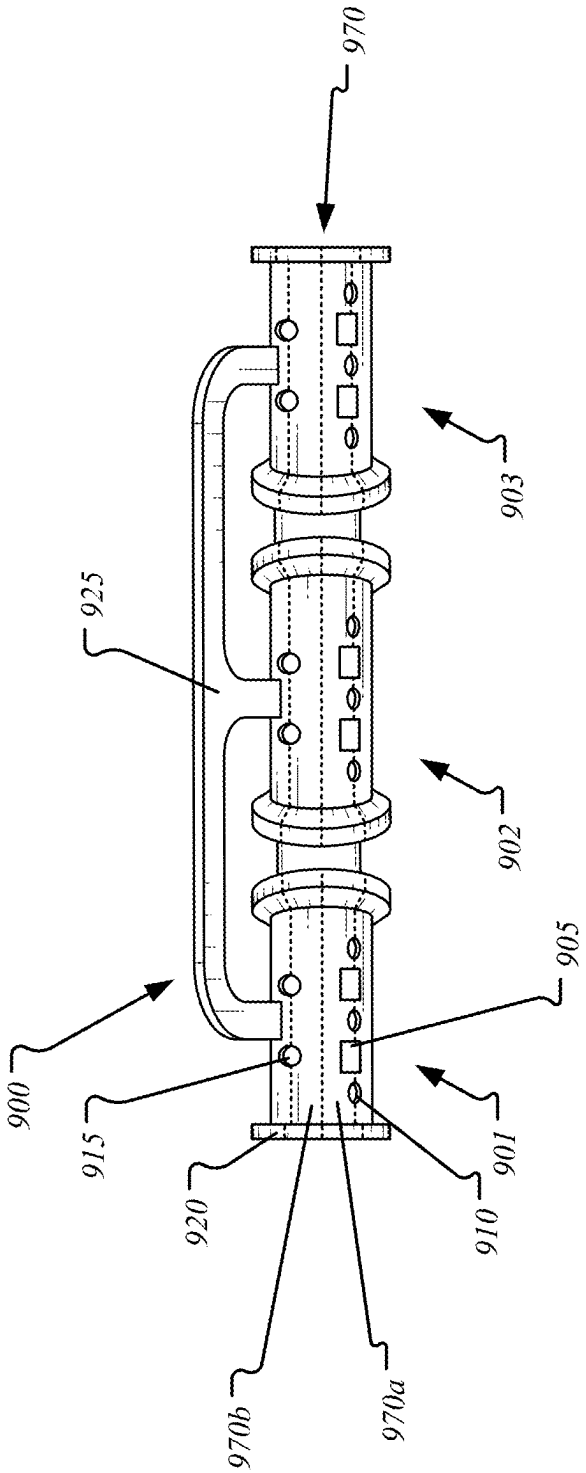


FIG. 4D

FIG. 4E



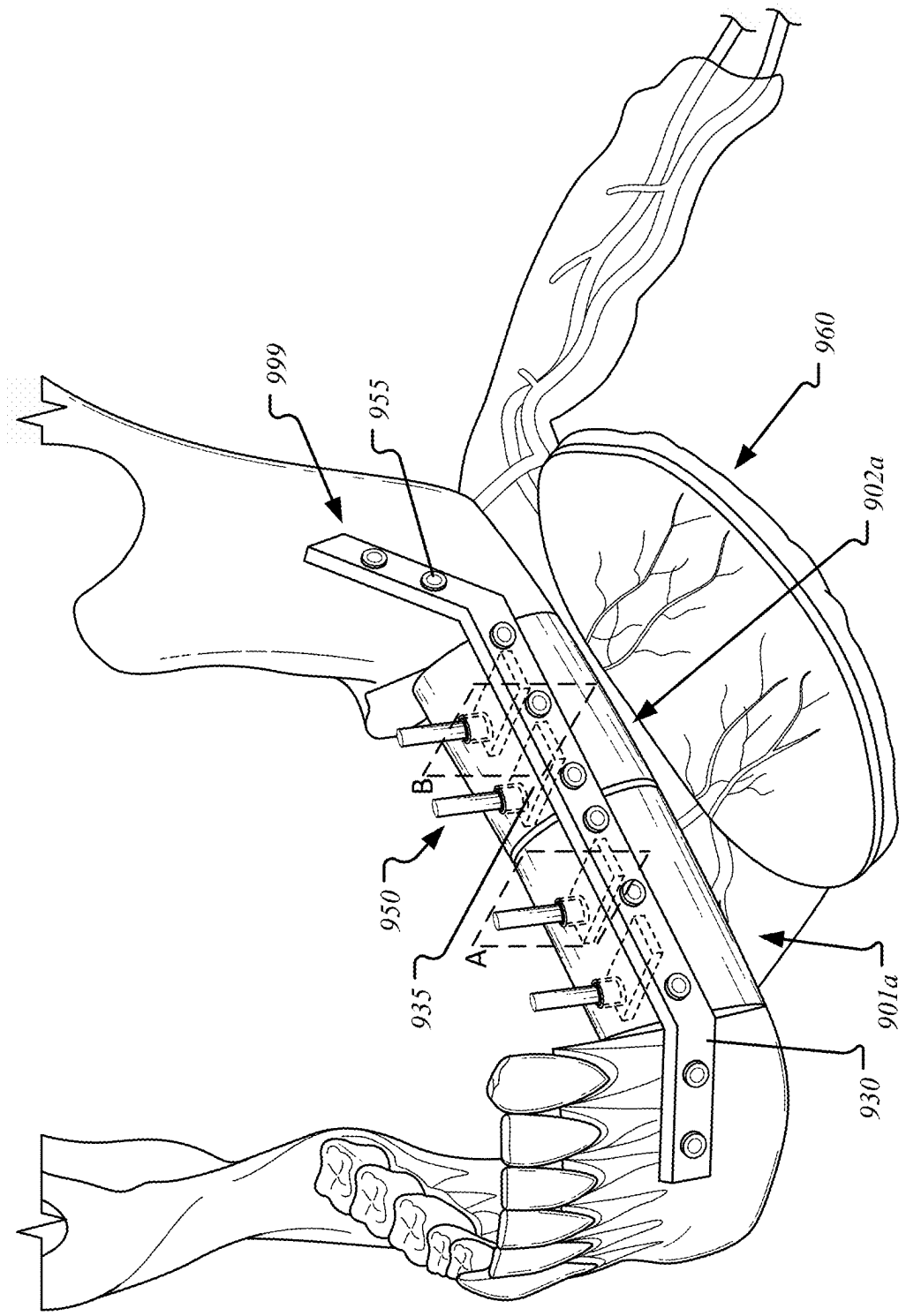


FIG. 5

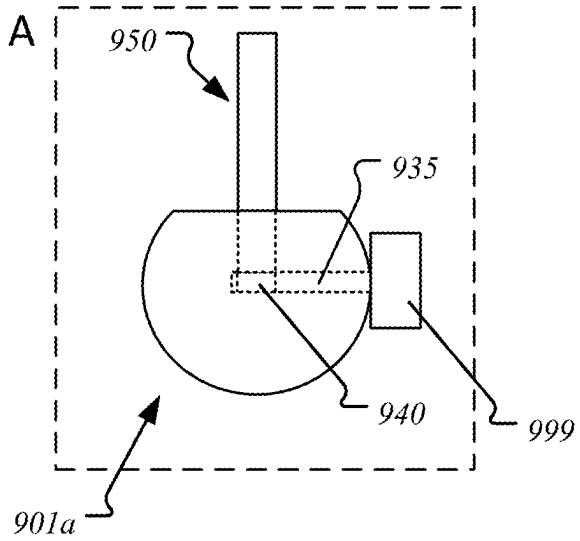


FIG. 6A

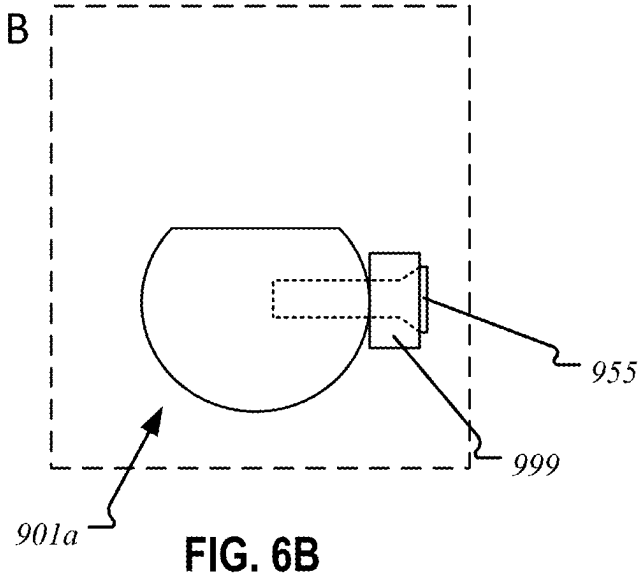


FIG. 6B

TRANSOSSEOUS BONE PLATE FOR FIBULA FLAP AND DENTAL IMPLANT RECONSTRUCTION

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims priority to U.S. Provisional Application No. 63/556,156, filed Feb. 21, 2024, which is incorporated herein by reference in its entirety for all purposes.

BACKGROUND

Field of the Disclosure

[0002] The present disclosure relates to a customized bone cutting template and reconstruction plate for mandible reconstruction using a donor bone with integrated dental implant support.

Description of the Related Art

[0003] Some dental implants replace missing teeth with root-form analogs which include titanium devices shaped in bone screws surgically placed into dentoalveolar structures with specialized platforms protruding through the crest of the dentoalveolus to mount dental prostheses. The dental implants are screwed through the crest of the dentoalveolus after drills prepare an osteotomy of appropriate diameter and length to receive the bone screw portion of a dental implant.

[0004] The foregoing description is for the purpose of generally presenting the context of the disclosure. Work of the inventors, to the extent it is described in this background section, as well as aspects of the description which may not otherwise qualify as prior art at the time of filing, are neither expressly or impliedly admitted as prior art against the present disclosure.

SUMMARY

[0005] The foregoing paragraphs have been provided by way of general introduction, and are not intended to limit the scope of the following claims. The described embodiments, together with further advantages, will be best understood by reference to the following detailed description taken in conjunction with the accompanying drawings.

[0006] In one embodiment, the present disclosure is related to a mandible reconstruction and dental implant system, including a first reconstruction template, including a body, a first cutting guide disposed at a first edge of the body and a second cutting guide disposed at a second edge of the body, a first plantar plate slot template disposed along the body, the first plantar plate slot template being an opening configured to receive a drill therein, a first bone fastener template disposed along the body, the first bone fastener template being an opening configured to receive the drill therein, and a first implant template disposed along the body and aligned with the first plantar plate slot template, the first implant template being an opening configured to receive a drill therein, an axis through the first implant template being orthogonal to an axis through the first plantar plate slot template; and a reconstruction plate, including a main bracket, and a first plantar plate protruding orthogonally from the main bracket, the first plantar plate including an aperture.

[0007] In one embodiment, the present disclosure is additionally related to a method of reconstructing a mandible, including obtaining a dental image of the mandible including a degraded portion for resection; attaching a reconstruction template to a donor bone, the reconstruction template including a body, a first cutting guide disposed at a first edge of the body and a second cutting guide disposed at a second edge of the body, a first plantar plate slot template disposed along the body, the first plantar plate slot template being an opening configured to receive a drill therein, a first bone fastener template disposed along the body, the first bone fastener template being an opening configured to receive the drill therein, and a first implant template disposed along the body and aligned with the first plantar plate slot template, the first implant template being an opening configured to receive a drill therein, an axis through the first implant template being orthogonal to an axis through the first plantar plate slot template; forming openings in the donor bone using the first plantar plate slot template, the first bone fastener template, and the first implant template; cutting the donor bone along the first cutting guide and the second cutting guide to generate a first bone segment; attaching a reconstruction plate to the first bone segment via the opening corresponding to the first plantar plate slot template, the reconstruction plate including a main bracket and a first plantar plate protruding orthogonally from the main bracket, the first plantar plate including an aperture; attaching the reconstruction plate with the attached first bone segment to the mandible; and attaching a dental implant to the first plantar plate through the attached first bone segment via the opening formed corresponding to the implant template.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] A more complete appreciation of the disclosure and many of the attendant advantages thereof will be readily obtained as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings, wherein:

[0009] FIG. **1** shows a schematic of a reconstruction template, according to an embodiment of the present disclosure.

[0010] FIG. **2** shows a schematic of the reconstruction template attached to a bone during a clinical procedure, according to an embodiment of the present disclosure.

[0011] FIG. **3**A shows a schematic of the reconstruction template attached to the fibula with a view along the top, according to an embodiment of the present disclosure.

[0012] FIG. **3**B shows a schematic of bone segments formed using the reconstruction template **900**, according to an embodiment of the present disclosure.

[0013] FIG. **3**C shows a schematic of a reconstruction plate (also known as a bone plate), according to an embodiment of the present disclosure.

[0014] FIG. **3**D shows a schematic of a transalveolar dental implant (TDI) system including a dental post with a threaded apex engaged therein, according to an embodiment of the present disclosure.

[0015] FIG. **4**A shows the plantar plate inserted into the plantar plate slot and secured using a positioning pin, according to an embodiment of the present disclosure.

[0016] FIG. **4**B shows a schematic of the positioning pin secured to the plantar plate, according to an embodiment of the present disclosure.

[0017] FIG. **4**C shows a schematic of the first bone segment attached to the reconstruction plate **999**, according to an embodiment of the present disclosure.

[0018] FIG. **4**D shows a schematic of a dental implant installed in a bone fragment, according to an embodiment of the present disclosure.

[0019] FIG. **4**E shows a schematic of the bone template **900** with removable pieces, according to an embodiment of the present disclosure.

[0020] FIG. **5** shows a schematic of a reconstructed mandible, according to an embodiment of the present disclosure.

[0021] FIG. **6**A shows a cross-sectional schematic of plane A, according to an embodiment of the present disclosure.

[0022] FIG. **6**B shows a cross-sectional schematic of plane B, according to an embodiment of the present disclosure.

DETAILED DESCRIPTION

[0023] The terms "a" or "an", as used herein, are defined as one or more than one. The term "plurality", as used herein, is defined as two or more than two. The term "another", as used herein, is defined as at least a second or more. The terms "including" and/or "having", as used herein, are defined as comprising (i.e., open language). Reference throughout this document to "one embodiment", "certain embodiments", "an embodiment", "an implementation", "an example" or similar terms means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment of the present disclosure. Thus, the appearances of such phrases or in various places throughout this specification are not necessarily all referring to the same embodiment. Furthermore, the particular features, structures, or characteristics may be combined in any suitable manner in one or more embodiments without limitation.

[0024] A mandibulectomy is a surgery to remove all or part of a jaw (mandible), which can be performed to remove a tumor, lesion, and/or necrosis that affects the jaw. Notably, the removed portions of the jaw can be reconstructed or replaced using bone from another part of the body, or a donor site. For example, the donor site can be the fibula bone, along with surrounding muscle, soft tissue, skin, veins, and arteries, which is also known as the fibula free flap.

[0025] During the course of the procedure to remove a portion of the mandible and reconstruct the mandible, the fibula bone can be cut into multiple segments and adjusted to fit in the removed portion of the mandible, and subsequently attached to a support structure that is fixated to the remaining mandible stumps flanking the removed portion. However, the process of aligning, stabilizing, and attaching the fibula bone segments to the support structure can often be cumbersome, inconsistent, and time consuming.

[0026] Furthermore, generally after the reconstruction of the mandible, patients can opt for another procedure to place dental implants along the reconstructed portion. This can require additional invasive work and another recovery period for the patient. This can also come at great expense to the patient since often times only the mandible reconstruction may be covered by health insurance, while the implant procedure would come at a cost to the patient.

[0027] Therefore, described herein is an apparatus, system, and method for a custom transosseous reconstruction bone plate for fibula free flap and dental implant reconstruction following a mandible resection.

[0028] In an embodiment, the bone plate can be contoured to align and fixate fibula bone segments to reconstruct a mandibular defect. The bone plate can be formed via, for example, additive manufacturing using a material such as titanium. The bone plate can include plantar plate features approximately 8 mm×8 mm in width and length and 2 mm thick, and can project horizontally from an inner surface of the bone plate and insert into osteotomy slots precisely formed into the fibula bone segments to assist in bone segment alignment. An aperture, such as a threaded 2.5 mm diameter aperture, can be included in the plantar plate and oriented to align with a planned dental implant osteotomy from the crest of the fibula used to reconstruct the fibula-mandible with dental implants to support a dental prosthesis for immediate return-to-function.

[0029] A drill guidance apparatus can be used to align and drill the dental implant osteotomy. After osteotomy, a dental post with a threaded apex feature can screw into the fibula-mandible and lock into the plantar plate feature of the bone plate. The dental implants can be inserted and locked into the plantar plate via the aperture and further fixate the fibula segments and provide a dental implant platform for immediate-function dental prosthesis reconstruction.

[0030] To this end, FIG. **1** shows a schematic of a reconstruction template **900**, according to an embodiment of the present disclosure. In an embodiment, the reconstruction template **900** includes a first template segment **901**, a second template segment **902**, and a third template segment **903**, but can also include any number of the template segments, such as just the first template segment **901**. When the reconstruction template **900** includes more than one of the template segments, the template segments can be connected by a template segment connector **925**. As shown, the template segment connector **925** can connect the first template segment **901**, the second template segment **902**, and the third template segment **903** together. The first template segment **901**, the second template segment **902**, and the third template segment **903** can each be configured to reversibly attach to a portion of a bone, such as a fibula bone, and provide aids for guiding the cutting, drilling, and adjustment of the bone to which the reconstruction template **900** is attached. For example, the first template segment **901** can include a plantar plate slot template **905**, a bone fastener template **910**, an implant template **915**, and a cutting guide **920**. In an embodiment, the first template segment **901**, the second template segment **902**, and the third template segment **903** can each be generally cylindrical in shape and hollow to receive the bone. As shown, the first template segment **901**, the second template segment **902**, and the third template segment **903** can include a shaft-like or cylindrical body with flared edges (described below). Of course, based on medical images obtained of the target bone on which the reconstruction template **900** will be attached, a shape of the first template segment **901**, the second template segment **902**, and the third template segment **903** can be customized to better fit on the target bone in the medical image.

[0031] In an embodiment, a material of the reconstruction template **900** is reversibly deformable (elastic) and the shape of the first template segment **901**, the second template segment **902**, and the third template segment **903** can be C-shaped to allow the C-shape to deform or open when forced onto the bone, and then deform back or close onto the bone to secure the reconstruction template **900** to the bone. The shape as described can be a cross-sectional shape taken

orthogonal to the axis of the bone (or hollow portion of the reconstruction template **900** when a bone is not disposed therein). In an embodiment, the material of the reconstruction template **900** is rigid and the first template segment **901**, the second template segment **902**, and the third template segment **903** can comprise multiple portions each that can be opened, arranged on the bone, and then closed and reversibly secured in the closed state until the bone has been successfully cut, drilled, or otherwise adjusted. For example, each of the first template segment **901**, the second template segment **902**, and the third template segment **903** can comprise two halves (a split C-shape, or two hemispheres for a fully circular enclosed shape) that are secured to one another via a push fit lock, twist lock, fastener, clamp, etc.

[0032] For example, each of the first template segment **901**, the second template segment **902**, and the third template segment **903** can comprise two halves and a first half of the two halves can include a first magnet configured to attract a second complementary magnet in a second half of the two halves to reversibly couple the first half to the second half. The first magnet and the second complementary magnet can have sufficient magnetic strength when coupled to keep the first template segment **901** (or any other template segment) closed around any bone segment arranged therein during a procedure where the bone segment is relocated. In an embodiment, the first magnet and/or the second complementary magnet can be electromagnets and configured to generate a magnetic field in response to a current. In such an example, the reconstruction template **900** can include a power source, circuitry, and a switch (not shown) for each template segment to toggle the electromagnet between an on or an off state to couple or uncouple the two halves by adjusting the flow of current to the electromagnets.

[0033] In an embodiment, the shape of the first template segment **901**, the second template segment **902**, and the third template segment **903** can be a half-circle or less and the reconstruction template **900** can be held in place by the operator against the bone.

[0034] In an embodiment, the plantar plate slot template **905** can be an opening in the first template segment **901**. The shape of the opening can have a cross-sectional shape that can be designed to receive a corresponding feature having a similar or complementary cross-sectional shape. As shown, the cross-sectional shape of the plantar plate slot template **905** can be rectangular and the plantar plate slot template **905** can be configured to receive a corresponding feature having a complementary rectangular cross-sectional shape inserted therein. For example, as will be described herein, the plantar plate slot template **905** can be configured to receive a plantar plate. The cross-sectional shape can be selected to ensure a particular orientation of the corresponding feature inserted therein, such a unique shape or shape having no rotational symmetry. Thus, the plantar plate slot template **905** can be configured to, when attached to a bone, receive an instrument or tool therein to cut, drill or otherwise adjust the bone via the opening that is the plantar plate slot template **905**. While the first template segment **901** is shown as having two of the plantar plate slot template **905**, the first template segment **901** can have any number n of the plantar plate slot template **905**, such as only one of the plantar plate slot template **905**, three of the plantar plate slot template **905**, etc.

[0035] In an embodiment, the bone fastener template **910** can be an opening in the first template segment **901**. The shape of the opening can have a cross-sectional shape that can be designed to receive a corresponding feature having a similar or complementary cross-sectional shape. As shown, the cross-sectional shape of the bone fastener template **910** can be circular and the bone fastener template **910** can be configured to receive a corresponding feature having a complementary circular cross-sectional shape inserted therein. For example, as will be described herein, the bone fastener template **910** can be configured to receive a fastener, such as a bone screw. Thus, the bone fastener template **910** can be configured to, when attached to a bone, receive an instrument or tool therein to cut, drill or otherwise adjust the bone via the opening that is the bone fastener template **910**. For example, the bone fastener template **910** can receive a drill bit and the drill bit can remove material from the bone to provide a pilot hole for the bone screw. While the first template segment **901** is shown as having two of the bone fastener template **910**, the first template segment **901** can have any number n of the bone fastener template **910**, such as only one of the bone fastener template **910**, three of the bone fastener template **910**, etc. As shown, an arrangement of the plantar plate slot template **905** and the bone fastener template **910** on the first template segment **901** can be relatively proximal along a same line. With relation to an axis through a length of the bone, the plantar plate slot template **905** and the bone fastener template **910** can be aligned at a same rotational angle. It may be appreciated that the arrangement of the plantar plate slot template **905** and the bone fastener template **910** need not be in alignment and can be at different rotational angles to one another.

[0036] In an embodiment, the implant template **915** can be an opening in the first template segment **901**. The shape of the opening can have a cross-sectional shape that can be designed to receive a corresponding feature having a similar or complementary cross-sectional shape. As shown, the cross-sectional shape of the implant template **915** can be circular and the implant template **915** can be configured to receive a corresponding feature having a complementary circular cross-sectional shape inserted therein. For example, as will be described herein, the implant template **915** can be configured to receive a dental implant post. Thus, the implant template **915** can be configured to, when attached to a bone, receive an instrument or tool therein to cut, drill or otherwise adjust the bone via the opening that is the implant template **915**. For example, the implant template **915** can receive a drill bit and the drill bit can remove material from the bone to provide a guide hole to the plantar plate slot template **905** for the dental implant post to be inserted and couple with the plantar plate. While the first template segment **901** is shown as having two of the implant template **915**, the first template segment **901** can have any number n of the implant template **915**, such as only one of the implant template **915**, three of the implant template **915**, etc. As shown, an arrangement of the implant template **915** can be at an orthogonal rotational angle to the plantar plate slot template **905**. That is, with relation to the axis through the length of the bone, the bone fastener template **910** and the implant template **915** can be arranged at an orthogonal rotational angle. It may be appreciated that the arrangement of the plantar plate slot template **905** and the implant template **915** need not be in any particular alignment or orthogonality and can be at different rotational angles to one another.

[0037] In an embodiment, although the plantar plate slot template **905**, the bone fastener template **910**, and the implant template **915** are shown as being openings having a thickness equal to a thickness of the shaft forming the main body of the first template segment **901**, the second template segment **902**, and the third template segment **903**, the plantar plate slot template **905**, the bone fastener template **910**, and the implant template **915** can be raised or extruded features (and hollowed through both ends of the openings) with a substantially larger thickness in order to further help guide the drill bit inserted therein. This can ensure a desired drill angle relative to the arrangement on the shaft of the first template segment **901**, the second template segment **902**, and the third template segment **903**. For example, an axis through the extruded openings can be orthogonal to the axis through the bone and orthogonal to a plane tangent to the location of the opening (the plantar plate slot template **905**, the bone fastener template **910**, or the implant template **915**).

[0038] In an embodiment, the cutting guide **920** can be a flared edge of the first template segment **901** having a planar face. The planar face can be configured to aid in guiding an instrument or tool in cutting the bone. For example, a blade can press against the cutting guide **920** on one side of the bone to which the reconstruction template **900** is attached, then translated to cut through the bone while being pressed against the cutting guide **920**, and the resulting cut of the bone will be a planar face as well. As shown, the cutting guide **920** along a left edge of the first template segment **901** can be orthogonal the axis of the bone (or the axis of the cylindrical shape of the first template segment **901**), while the cutting guide **920** along a right edge of the first template segment **901** can have a predetermined angle. Thus, the resulting planes of the edges of the cut bone need not be parallel to one another. This can help with final fit of the cut bone segments when arranged together in the mandible to form any desired curves. In an embodiment, the angle can be customized based on a medical image obtained of the mandible. When multiple pieces of bone are needed to reconstruct the mandible, multiple of the angled cutting guide **920** can be customized for each of the template segments, such as for forming a curved mandible portion.

[0039] FIG. **2** shows a schematic of the reconstruction template **900** attached to a bone during a clinical procedure, according to an embodiment of the present disclosure. In an embodiment, a fibula bone (or for simplicity, also referred to as "the fibula") of a patient can be used as the donor site for the bone needed to reconstruct the patient's mandible. Thus, as shown, the leg of the patient can be cut open to reveal the fibula, and the reconstruction template **900** can be applied or attached to the fibula.

[0040] FIG. **3**A shows a schematic of the reconstruction template **900** attached to the fibula with a view along the top, according to an embodiment of the present disclosure. In an embodiment, the fibula bone can be cut via the reconstruction template **900** for each of the template segments and each of the plantar plate slot template **905**, the bone fastener template **910**, and the implant template **915** can be used to drill or adjust the corresponding bone segments. Here, a see-through view of the implant template **915** is shown to illustrate the connection from the implant template **915** to the plantar plate slot template **905** when the bone has been drilled, where eventually a plantar plate can be inserted into the bone segment via the plantar plate slot template **905** and a dental implant can be inserted via the implant template **915** and couple with the plantar plate.

[0041] FIG. **3**B shows a schematic of bone segments formed using the reconstruction template **900**, according to an embodiment of the present disclosure. In an embodiment, the reconstruction template **900** can be used to generate a first bone segment **901***a*, a second bone segment **902***a*, and a third bone segment **903***a*. Each of the first bone segment **901***a*, the second bone segment **902***a*, and the third bone segment **903***a* can include a plantar plate slot **905***a*, a bone attachment opening **910***a*, and a dental implant opening **915***a*. As shown, the two of the plantar plate slot template **905** can be used to form the corresponding two of the plantar plate slot **905***a*, the three of the bone fastener template **910** can be used to form the corresponding three of the bone attachment opening **910***a*, and the two of the implant template **915** can be used to form the corresponding two of the dental implant opening **915***a*. The first bone segment **901***a* is also shown to have an angled cut along a right side of the first bone segment **901***a*, the second bone segment **902***a* is shown to have an angled cut along both a left and a right side of the second bone segment **902***a*, and the third bone segment **903***a* is shown to have an angled cut along a left side of the third bone segment **903***a* based on the angled cutting guide **920** for the reconstruction template **900** shown in FIGS. **1** and **2**. Again, the dental implant opening **915***a* formed via the implant template **915** is shown as traversing through the bone segments to meet with the plantar plate slot **905***a*, and the plantar plate slot **905***a* can be configured to receive a plantar plate.

[0042] To this end, FIG. **3**C shows a schematic of a reconstruction plate **999** (also known as a bone plate), according to an embodiment of the present disclosure. In an embodiment, the reconstruction plate **999** can be a support structure configured to couple with the first bone segment **901***a*, the second bone segment **902***a*, and the third bone segment **903***a*. The reconstruction plate **999** can have a shape that is based on the removed portion of the mandible. As shown in FIG. **3**C, the reconstruction plate **999** can include a main bracket **930**, and the main bracket **930** can be curved. The reconstruction plate **999** can be formed by, for example, additive manufacturing, molding, stamping, and CNC machining, among others. The reconstruction plate **999** can include a plantar plate **935**, or multiple of the plantar plate **935**, and the plantar plate **935** can include a aperture **940**. The plantar plate **935** can be a protrusion from the main bracket **930** and have a rectangular shape, or any complementary shape to insert into the plantar plate slot **905***a*. The plantar plate **935** can be in singles or multiples to couple with the bone fragments. For the reconstruction plate **999** shown in FIG. **3**C, a group of two of the plantar plate **935** can couple with a bone fragment having two of the plantar plate slot **905***a*, while a single of the plantar plate **935** can couple with a bone fragment having just one of the plantar plate slot **905***a*. A length of the plantar plate **935** can be, for example, 2 mm to 20 mm, or 4 to 15 mm, or 6 to 10 mm, or approximately 8 mm. A width of the plantar plate **935** can be, for example, 2 mm to 20 mm, or 4 to 15 mm, or 6 to 10 mm, or approximately 8 mm. A thickness of the plantar plate **935** can be, for example, 0.5 mm to 5 mm, or 1 mm to 4 mm, or approximately 2 mm. A diameter of the aperture **940** can be, for example, 1 mm to 5 mm, or 2 mm to 4 mm, or approximately 2.5 mm.

[0043] FIG. **3**D shows a schematic of a transalveolar dental implant (TDI) system including a dental post with a threaded apex engaged therein, according to an embodiment of the present disclosure. In an embodiment, the TDI system can include a TDI dental post **212** with a threaded apex to frictionally lock into a corresponding threaded aperture of a previously positioned and affixed TDI bone plate **205**, in situ. In an embodiment, the TDI bone plate **205** can include two portions: a first portion **242** can be a planar portion **242** and a second portion **244** can be a contoured portion **244**. Notably, the planar portion **242** can be similar to the plantar plate **935**, including the aperture being akin to the aperture **940** of the plantar plate **935**. Similarly, the TDI dental post **212** that is installed in the aperture of the planar portion **242** can be installed in the aperture **940**.

[0044] In a clinical setting, the coupling of the bone fragment to the reconstruction plate **999** via the plantar plate **935** can be easier to accomplish compared to coupling of the bone fragment to a reconstruction plate lacking the plantar plate **935**. That is, once the bone fragment has been cut from the donor bone, such as the first bone segment **901***a* having two of the plantar plate slot **905***a*, the first bone segment **901***a* can be easily coupled with the reconstruction plate **999** by inserting the plantar plate **935** into the plantar plate slot **905***a*. Once coupled, the first bone segment **901***a* range of motion can be reduced significantly, thereby preventing the slipping of the first bone segment **901***a* relative to the reconstruction plate **999**. As previously mentioned, this part of the reconstruction process represents one of the most clumsy, inconsistent, and time-consuming steps since operators will often try to stabilize the bone fragment by hand while trying to attach the bone fragment to the reconstruction plate since a right angle of the fastener into the reconstruction plate is desired. Furthermore, the mishandling of the bone fragments is magnified by the fluids surrounding the donor site and on the bone fragments, such as blood. Thus, the insertion of the plantar plate **935** into the plantar plate slot **905***a* restricts all but one range of motion, which can be further restricted by applying a temporary fastener.

[0045] To this end, FIG. **4**A shows the plantar plate **935** inserted into the plantar plate slot **905***a* and secured using a positioning pin **945**, according to an embodiment of the present disclosure. In an embodiment, a shaft of the positioning pin **945** can be inserted into and through the dental implant opening **915***a*, and a tip of the positioning pin **945** can couple with the aperture **940** of the plantar plate **935**.

[0046] FIG. **4**B shows a schematic of the positioning pin **945** secured to the plantar plate **935**, according to an embodiment of the present disclosure. In an embodiment, upon coupling of the positioning pin **945** with the plantar plate **935**, the first bone segment **901***a* can be secured to the reconstruction plate **999** and all ranges of motion of the first bone segment **901***a* can be restricted. For example, the tip of the positioning pin **945** can be threaded and the aperture **940** can be threaded with a complementary threading. For example, the tip of the positioning pin **945** can be push fit into the aperture **940** having a size, shape, or dimension configured to secure the tip of the positioning pin **945** in the aperture **940**. For example, the tip of the positioning pin **945** can be twist fit into the aperture **940** having a size, shape, or dimension configured to secure the tip of the positioning pin **945** in the aperture **940**. For example, the tip of the positioning pin **945** can be generally friction fit into the aperture **940**. For example, the tip of the positioning pin **945** can be magnetic and the aperture **940** can include a complementary magnet configured to attract the magnetic tip of the positioning pin **945**.

[0047] FIG. **4**C shows a schematic of the first bone segment **901***a* attached to the reconstruction plate **999**, according to an embodiment of the present disclosure. In an embodiment, the first bone segment **901***a* (or the second bone segment **902***a*, or the third bone segment **903***a*) can be coupled to the reconstruction plate **999** as previously described via inserting the plantar plate **935** into the plantar plate slot **905***a*, and the first bone segment **901***a* can be temporarily secured to the reconstruction plate **999** via the positioning pin **945** inserted through the dental implant opening **915***a* and into the aperture **940** of the plantar plate **935**. Once temporarily secured to the reconstruction plate **999**, a fastener **955** (or multiple of the fastener **955**) can be used to secure the first bone segment **901***a* to the reconstruction plate **999** via the bone attachment opening **910***a*. The fastener **955** can be, for example, a bone screw. As shown, the main bracket **930** of the reconstruction plate **999** can include various openings or fastening locations through which the fastener **955** can be inserted and then engaged with the first bone segment **901***a*. At this point in the procedure, the reconstruction plate **999** can be fixated to the flanking mandible stumps and the first bone segment **901***a* (and any additional bone fragments) can be coupled to the reconstruction plate **999**, and the procedure can optionally end with the positioning pin **945** in place, or removed with the dental implant opening **915***a* covered or filled using an alternative feature. Additionally or alternatively, the procedure can continue with a dental implant implanted into the dental implant opening **915***a*.

[0048] To this end, FIG. **4**D shows a schematic of a dental implant installed in a bone fragment, according to an embodiment of the present disclosure. In an embodiment, the mandible reconstruction can further include implanting a dental implant **950** in the first bone segment **901***a*. As previously described, after the reconstruction of the mandible and full recovery, patients can opt for another follow-up procedure to place dental implants along the reconstructed portion. This can require additional invasive work and another separate recovery period for the patient. This can also come at great expense to the patient since often times only the mandible reconstruction may be covered by health insurance. Thus, the implant template **915** can be used to form the dental implant opening **915***a* through which the dental implant **950** can be inserted and coupled to the plantar plate **935** via the aperture **940** in the same procedure. As shown, an apex of the dental implant **950** can include a fastening feature. For example, the apex of the dental implant **950** can be threaded and the aperture **940** can be threaded with a complementary threading. For example, the apex of the dental implant **950** can be push fit into the aperture **940** having a size, shape, or dimension configured to secure the apex of the dental implant **950** in the aperture **940**. For example, the apex of the dental implant **950** can be twist fit into the aperture **940** having a size, shape, or dimension configured to secure the apex of the dental implant **950** in the aperture **940**. For example, the apex of the dental implant **950** can be generally friction fit into the aperture **940**. For example, the apex of the dental implant **950** can be magnetic and the aperture **940** can include a complementary magnet configured to attract the magnetic

apex of the dental implant **950**. The opposite end of the dental implant **950** from the apex can be configured to receive additional dental devices and prostheses, such as a replacement tooth. The dental implant **950** need not receive the additional dental devices and prostheses immediately and can be quickly attached to the dental implant **950** at a later point in time (without requiring an additional invasive procedure).

[0049] In an embodiment, the bone fragment(s) can remain in the bone template **900** for even easier handling during coupling of the bone segments to the bone plate. To this end, FIG. **4**E shows a schematic of the bone template **900** with removable pieces, according to an embodiment of the present disclosure. In an embodiment, the bone template **900** can include, for each of the template segments, one or more breakaway portion **970** denoted by the dotted lines through the template segments. For example, as shown, the first template segment **901** includes a first breakaway portion **970***a*. The one or more breakaway portion **970** can be a segment of material formed as part of the first template segment **901** that is configured to separate from the first template segment **901**. In such an example, the first bone fragment **901***a*, while still arranged in the first template segment **901**, can have the plantar plate **935** inserted into the plantar plate slot **905***a* through the plantar plate slot template **905** of the first template segment **901**. For example, the operator can hold the template segment connector with one hand and, with the other hand, manipulate the first template segment **901** (with the first bone segment **901***a* arranged therein) to insert the plantar plate **935** through both the plantar plate slot template **905***a* and the plantar plate slot **905**. Upon sufficient insertion of the plantar plate **935** into the plantar plate slot **905***a* to prevent unwanted motion of the first bone segment **901***a*, the first breakaway portion **970***a* can be separated and removed from the first template segment **901**. For example, the first breakaway portion **970***a* can be attached to the first template segment **901** at a plurality of connectors configured to be easily broken during the procedure to separate the first breakaway portion **970***a* from the rest of the first template segment **901**. For example, the operator can use a small drill or saw to cut through the plurality of connectors. A material of the bone template **900** can be a polymer or metal. The bone plate **900** can be fabricated via, for example, additive manufacturing (e.g., 3D printing), injection molding, CNC machining, die casting, or similar.

[0050] As shown, for example, a first edge of the first breakaway portion **970***a* can run through a middle of the plantar plate slot templates **905***a*. Therefore, removing the first breakaway portion **970***a* allows the first template segment **901** to release or separate from the plantar plates **935** and the bone plate **999**. Notably, when the bone fastener templates **910** are aligned with the plantar plate slot templates **905***a*, the fasteners **955** (described below) can also be partially fastened at this stage through the bone fastener templates **910** to further prevent unwanted motion of the first bone segment **901***a* and begin coupling of the first bone segment **901***a* to the bone plate **999**. Again, since the first edge of the first breakaway portion **970***a* runs through a middle of the bone fastener templates **910**, removing the first breakaway portion **970***a* allows the first template segment **901** to release or separate from the fasteners **955** and the bone plate **999**. Once the first breakaway portion **970***a* is removed, the plantar plates **935** can be fully inserted into the plantar plate slots **905***a*. At this point, the fasteners **955** can be fully fastened to the first bone segment **901***a* as well.

[0051] When the fasteners **955** are not yet used to fasten the first bone segment **901***a* to the bone plate **999**, the positioning pins **945** can be used instead to temporarily couple the first bone segment **901***a* to the plantar plate **935**. The positioning pins **945** can be inserted through the implant template **915** and into the dental implant opening **915***a*. The first template segment **901** can include a second breakaway portion **970***b* with a first edge of the second breakaway portion **970***b* running through a middle of the implant templates **915**. Therefore, removing the second breakaway portion **970***b* allows the first template segment **901** to release or separate from the positioning pins **945** while allowing the positioning pins **945** to remain coupled to the plantar plate **935**.

[0052] As previously described, the template segments can comprise two halves (a split C-shape, or two hemispheres for a fully circular enclosed shape) that are secured to one another via, for example, a push fit lock, twist lock, fastener, clamp, magnetic force, etc. Thus, in a similar manner as described above, the first bone fragment **901***a*, while still arranged in the first template segment **901**, can have the plantar plate **935** inserted into the plantar plate slot **905***a* through the plantar plate slot template **905** of the first template segment **901**. Then, the two halves can be separated from one another, the first template segment **901** can be released from the plantar plate **935** (and the bone plate **999**), and the plantar plate **935** can be fully inserted into the plantar plate slot **905***a*. For example, a push fit lock can be pulled with sufficient force to unlock the push fit lock and separate the two halves. For example, the switch can be activated to toggle power to the electromagnets securing the two halves to one another to the off state, thereby reducing the attraction of the electromagnets. Again, a set of abutting edges of the two halves can run through the middle of the plantar plate slot template **905** of the first template segment **901**. Therefore, separating the two halves of the first template segment **901** allows the first template segment **901** to release or separate from the plantar plates **935** and the bone plate **999**.

[0053] To summarize, an additional clinical example is described herein. In an embodiment, the fibula can be surrounded by vascular periosteum. Surgery to segmentalize the fibula can use a lateral approach with care to keep as much periosteum attached to the bone as possible. No more than, for example, a target 50% circumferential area of periosteum can be dissected off the bone. The vessels from the muscle can stay attached to the periosteum on the inner aspect of the fibula. The cutting guide **920** (C-clamps) of the bone template **900** can overlay the periosteum partially on an inner aspect in order to achieve, for example, at least 60% of clamp arranged or coupled onto the fibula.

[0054] The bone template **900**, and in particular, the target template segment can be stabilized by screws through the bone fastener templates **910**. The fibula can be segmentalized and the intersegment pieces (the bone segments **901***a*, **902***a*, **903***a*) can be removed. The intersegments can then be inserted onto plantar projections (the plantar plates **935**) of the bone plate **999** and the positioning pins **945** can be arranged or inserted through the dental implant opening **915***a* to lock into the (plantar) apertures **940**. As this is being performed, portions of the bone template **900** (the one or more breakaway portion **970**) can be peeled away or

removed, especially to expose the bone attachment opening **910***a* and the plantar plate slot **905***a* areas which will be seated against the main bracket **930** of the bone plate **999**.

[0055] The template segment connector **925** of the bone template **900** can be removed as an early step to bring butt ends of the intersegment pieces together. The other aspects of the bone template **900** can be removed early or late depending on clinical needs to hold onto wet and slippery intersegment pieces.

[0056] FIG. **5** shows a schematic of a reconstructed mandible, according to an embodiment of the present disclosure. In an embodiment, the reconstruction plate **999** can be fixated to the flanking mandible stumps via multiple of the fastener **955** disposed at various locations along the main bracket **930** of the reconstruction plate **999**. The first bone segment **901***a* and the second bone segment **902***a* shown can be attached to the plantar plate **935** of the reconstruction plate **999** and secured to the reconstruction plate **999** also via multiple of the fastener **955** disposed at various locations along the main bracket **930** of the reconstruction plate **999** corresponding to the locations of the bone attachment opening **910***a*, and the dental implant **950** can be inserted through the dental implant opening **915***a* and coupled to the aperture **940** of the plantar plate **935**. Also shown are arteries **960** from the fibula free flap that can be re-attached or reconnected to existing nearby arteries to provide a blood supply and vasculitis-free flap.

[0057] FIG. **6**A shows a cross-sectional schematic of plane A, according to an embodiment of the present disclosure. In an embodiment, the cross-sectional plane A shows an orthogonal view to the axis of the bone along where the dental implant **950** is coupled to the plantar plate **935** through the first bone segment **901***a* via the dental implant opening **915***a*. Also of note, the top portion of the first bone segment **901***a* is shown as being planarized instead of rounded. This planarization can be performed as desired based on the dental implant **950** used and eventual dental prostheses installed.

[0058] FIG. **6**B shows a cross-sectional schematic of plane B, according to an embodiment of the present disclosure. In an embodiment, the cross-sectional plane B shows an orthogonal view to the axis of the bone along where the fastener **955**, which is shown as a bone screw, has been screwed through the reconstruction plate **999** and into the first bone segment **901***a* to secure the main bracket **930** to the first bone segment **901***a*.

[0059] While this specification contains many specific implementation details, these should not be construed as limitations on the scope of what may be claimed, but rather as descriptions of features that may be specific to particular embodiments.

[0060] Certain features that are described in this specification in the context of separate embodiments can also be implemented in combination in a single embodiment. Conversely, various features that are described in the context of a single embodiment can also be implemented in multiple embodiments separately or in any suitable sub-combination. Moreover, although features may be described above as acting in certain combinations and even initially claimed as such, one or more features from a claimed combination can in some cases be excised from the combination, and the claimed combination may be directed to a sub-combination or variation of a sub-combination.

[0061] Similarly, while operations are depicted in the drawings in a particular order, this should not be understood as requiring that such operations be performed in the particular order shown or in sequential order, or that all illustrated operations be performed, to achieve desirable results. In certain circumstances, multitasking and parallel processing may be advantageous. Moreover, the separation of various system modules and components in the embodiments described above should not be understood as requiring such separation in all embodiments, and it should be understood that the described program components and systems can generally be integrated together in a single software product or packaged into multiple software products.

[0062] Particular embodiments of the subject matter have been described. Other embodiments are within the scope of the following claims. For example, the actions recited in the claims can be performed in a different order and still achieve desirable results. As one example, the processes depicted in the accompanying figures do not necessarily require the particular order shown, or sequential order, to achieve desirable results. In some cases, multitasking and parallel processing may be advantageous.

[0063] Embodiments of the present disclosure may also be as set forth in the following parentheticals.

[0064] (1) A mandible reconstruction and dental implant system, including a first reconstruction template, including a body, a first cutting guide disposed at a first edge of the body and a second cutting guide disposed at a second edge of the body, a first plantar plate slot template disposed along the body, the first plantar plate slot template being an opening configured to receive a drill therein, a first bone fastener template disposed along the body, the first bone fastener template being an opening configured to receive the drill therein, and a first implant template disposed along the body and aligned with the first plantar plate slot template, the first implant template being an opening configured to receive a drill therein, an axis through the first implant template being orthogonal to an axis through the first plantar plate slot template; and a reconstruction plate, including a main bracket, and a first plantar plate protruding orthogonally from the main bracket, the first plantar plate including an aperture.

[0065] (2) The system of (1), wherein the main bracket includes at least one opening configured to receive a fastener therein to attach the main bracket to an abutting bone segment.

[0066] (3) The system of either (1) or (2), wherein the aperture includes threading for receiving and frictionally securing a complementary threading inserted therein.

[0067] (4) The system of any one of (1) to (3), further comprising a positioning pin configured to be inserted through an opening in a bone formed using the dental implant opening and coupled to the plantar plate.

[0068] (5) The system of any one of (1) to (4), further comprising a dental implant configured to be inserted through an opening in a bone formed using the dental implant opening and coupled to the plantar plate.

[0069] (6) The system of any one of (1) to (5), wherein an angle of a plane of the first cutting guide is based on an obtained medical image.

[0070] (7) The system of any one of (1) to (6), wherein an angle of a plane of the second cutting guide is based on the obtained medical image.

[0071] (8) The system of any one of (1) to (7), wherein a cross-sectional shape of the plantar plate slot template is rectangular, and a cross-sectional shape of the plantar plate is a complementary rectangular shape to the plantar plate slot template.

[0072] (9) The system of any one of (1) to (8), wherein a cross-sectional shape of the bone template is C-shaped and the bone template is configured to engage a donor bone via a push fit.

[0073] (10) The system of any one of (1) to (9), wherein a cross-sectional shape of the bone template is circular with split semicircles, and the bone template is configured to engage a donor bone by opening the bone template and arranging the bone template on the donor bone.

[0074] (11) The system of any one of (1) to (10), further comprising a second reconstruction template, the first reconstruction template and the second reconstruction template being attached to one another via a template segment connector.

[0075] (12) The system of any one of (1) to (11), wherein an arrangement of the plantar plate slot template is aligned with the bone fastener template along a length of the body.

[0076] (13) The system of any one of (1) to (12), wherein the arrangement of the bone fastener template is not aligned with the implant template along the length of the body.

[0077] (14) The system of any one of (1) to (13), wherein the reconstruction plate includes a second plantar plate slot disposed proximal to the first plantar plate slot and the reconstruction template includes a second plantar plate slot template arranged at a corresponding relative location as the first plantar plate slot to the second plantar plate slot.

[0078] (15) The system of any one of (1) to (14), wherein a material of the reconstruction plate is titanium and the reconstruction plate is formed via additive manufacturing.

[0079] (16) The system of any one of (1) to (15), wherein a first side of the main bracket of the reconstruction template is configured to be fixated to a first mandible stump and a second side of the main bracket of the reconstruction template is configured to be fixated to a second mandible stump.

[0080] (17) A reconstruction template apparatus, including a main bracket; and a first plantar plate protruding orthogonally from the main bracket, the first plantar plate including an aperture.

[0081] (18) The apparatus of (17), wherein the main bracket includes at least one opening configured to receive a fastener therein to attach the main bracket to an abutting bone segment.

[0082] (19) The apparatus of either (17) or (18), wherein the aperture includes threading for receiving and frictionally securing a complementary threading inserted therein.

[0083] (20) The apparatus of any one of (17) to (19), wherein a first side of the main bracket of the reconstruction template is configured to be fixated to a first mandible stump and a second side of the main bracket of the reconstruction template is configured to be fixated to a second mandible stump.

[0084] (21) A method of reconstructing a mandible, including obtaining a dental image of the mandible including a degraded portion for resection; attaching a reconstruction template to a donor bone, the reconstruction template including a body, a first cutting guide disposed at a first edge of the body and a second cutting guide disposed at a second edge of the body, a first plantar plate slot template disposed along the body, the first plantar plate slot template being an opening configured to receive a drill therein, a first bone fastener template disposed along the body, the first bone fastener template being an opening configured to receive the drill therein, and a first implant template disposed along the body and aligned with the first plantar plate slot template, the first implant template being an opening configured to receive a drill therein, an axis through the first implant template being orthogonal to an axis through the first plantar plate slot template; forming openings in the donor bone using the first plantar plate slot template, the first bone fastener template, and the first implant template; cutting the donor bone along the first cutting guide and the second cutting guide to generate a first bone segment; attaching a reconstruction plate to the first bone segment via the opening corresponding to the first plantar plate slot template, the reconstruction plate including a main bracket and a first plantar plate protruding orthogonally from the main bracket, the first plantar plate including an aperture; attaching the reconstruction plate with the attached first bone segment to the mandible; and attaching a dental implant to the first plantar plate through the attached first bone segment via the opening formed corresponding to the implant template.

[0085] Thus, the foregoing discussion discloses and describes merely exemplary embodiments of the present disclosure. As will be understood by those skilled in the art, the present disclosure may be embodied in other specific forms without departing from the spirit thereof. Accordingly, the disclosure of the present disclosure is intended to be illustrative, but not limiting of the scope of the disclosure, as well as other claims. The disclosure, including any readily discernible variants of the teachings herein, defines, in part, the scope of the foregoing claim terminology such that no inventive subject matter is dedicated to the public.

1. A mandible reconstruction and dental implant system, comprising:

a first reconstruction template, including

a body,

a first cutting guide disposed at a first edge of the body and a second cutting guide disposed at a second edge of the body,

a first plantar plate slot template disposed along the body, the first plantar plate slot template being an opening configured to receive a drill therein,

a first bone fastener template disposed along the body, the first bone fastener template being an opening configured to receive the drill therein, and

a first implant template disposed along the body and aligned with the first plantar plate slot template, the first implant template being an opening configured to receive a drill therein, an axis through the first

implant template being orthogonal to an axis through the first plantar plate slot template; and

a reconstruction plate, including

a main bracket, and

a first plantar plate protruding orthogonally from the main bracket, the first plantar plate including an aperture.

2. The system of claim **1**, wherein the main bracket includes at least one opening configured to receive a fastener therein to attach the main bracket to an abutting bone segment.

3. The system of claim **1**, wherein the aperture includes threading for receiving and frictionally securing a complementary threading inserted therein.

4. The system of claim **1**, further comprising a positioning pin configured to be inserted through an opening in a bone formed using the dental implant opening and coupled to the plantar plate.

5. The system of claim **1**, further comprising a dental implant configured to be inserted through an opening in a bone formed using the dental implant opening and coupled to the plantar plate.

6. The system of claim **1**, wherein an angle of a plane of the first cutting guide is based on an obtained medical image.

7. The system of claim **6**, wherein an angle of a plane of the second cutting guide is based on the obtained medical image.

8. The system of claim **1**, wherein

a cross-sectional shape of the plantar plate slot template is rectangular, and

a cross-sectional shape of the plantar plate is a complementary rectangular shape to the plantar plate slot template.

9. The system of claim **1**, wherein a cross-sectional shape of the bone template is C-shaped and the bone template is configured to engage a donor bone via a push fit.

10. The system of claim **1**, wherein a cross-sectional shape of the bone template is circular with split semicircles, and the bone template is configured to engage a donor bone by opening the bone template and arranging the bone template on the donor bone.

11. The system of claim **1**, further comprising a second reconstruction template, the first reconstruction template and the second reconstruction template being attached to one another via a template segment connector.

12. The system of claim **1**, wherein an arrangement of the plantar plate slot template is aligned with the bone fastener template along a length of the body.

13. The system of claim **12**, wherein the arrangement of the bone fastener template is not aligned with the implant template along the length of the body.

14. The system of claim **1**, wherein the reconstruction plate includes a second plantar plate slot disposed proximal to the first plantar plate slot and the reconstruction template includes a second plantar plate slot template arranged at a corresponding relative location as the first plantar plate slot to the second plantar plate slot.

15. The system of claim **1**, wherein a material of the reconstruction plate is titanium and the reconstruction plate is formed via additive manufacturing.

16. The system of claim **1**, wherein a first side of the main bracket of the reconstruction template is configured to be fixated to a first mandible stump and a second side of the main bracket of the reconstruction template is configured to be fixated to a second mandible stump.

17. A reconstruction template apparatus, comprising:

a main bracket; and

a first plantar plate protruding orthogonally from the main bracket, the first plantar plate including an aperture.

18. The apparatus of claim **17**, wherein the main bracket includes at least one opening configured to receive a fastener therein to attach the main bracket to an abutting bone segment.

19. The apparatus of claim **17**, wherein the aperture includes threading for receiving and frictionally securing a complementary threading inserted therein.

20. The apparatus of claim **17**, wherein a first side of the main bracket of the reconstruction template is configured to be fixated to a first mandible stump and a second side of the main bracket of the reconstruction template is configured to be fixated to a second mandible stump.

21. A method of reconstructing a mandible, comprising:

obtaining a dental image of the mandible including a degraded portion for resection;

attaching a reconstruction template to a donor bone, the reconstruction template including a body, a first cutting guide disposed at a first edge of the body and a second cutting guide disposed at a second edge of the body, a first plantar plate slot template disposed along the body, the first plantar plate slot template being an opening configured to receive a drill therein, a first bone fastener template disposed along the body, the first bone fastener template being an opening configured to receive the drill therein, and a first implant template disposed along the body and aligned with the first plantar plate slot template, the first implant template being an opening configured to receive a drill therein, an axis through the first implant template being orthogonal to an axis through the first plantar plate slot template;

forming openings in the donor bone using the first plantar plate slot template, the first bone fastener template, and the first implant template;

cutting the donor bone along the first cutting guide and the second cutting guide to generate a first bone segment;

attaching a reconstruction plate to the first bone segment via the opening corresponding to the first plantar plate slot template, the reconstruction plate including a main bracket and a first plantar plate protruding orthogonally from the main bracket, the first plantar plate including an aperture;

attaching the reconstruction plate with the attached first bone segment to the mandible; and

attaching a dental implant to the first plantar plate through the attached first bone segment via the opening formed corresponding to the implant template.

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