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(54) VARIABLE ANGLE LOCKING IMPLANT

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(58) **Field of Classification Search**
None
See application file for complete search history.

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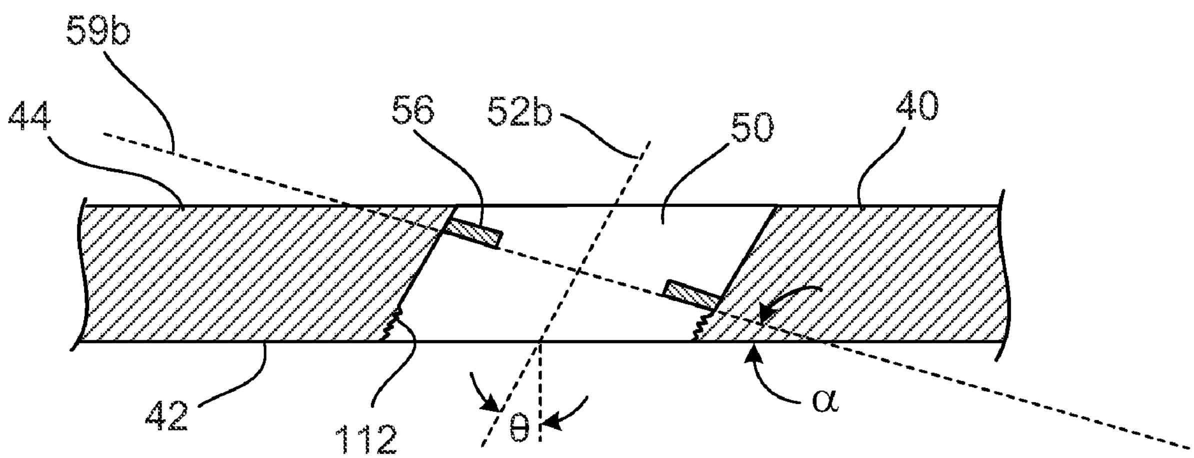
(57) **ABSTRACT**

A variable angle locking implant includes a bone plate having a lower surface, an upper surface, and at least one opening extending from the lower surface to the upper surface along an axis. The opening has a plurality of fins oriented along a plane. The axis is non-perpendicular to a tangent of a projection of the lower surface across the opening, the tangent defined at the intersection between the axis and the projected lower surface, and/or the plane is non-parallel to the tangent. The implant includes at least one fastener, and the plurality of fins are deflectable relative to a head portion of the fastener such that the fastener can be inserted and retained at any one of a plurality of angles.

18 Claims, 4 Drawing Sheets



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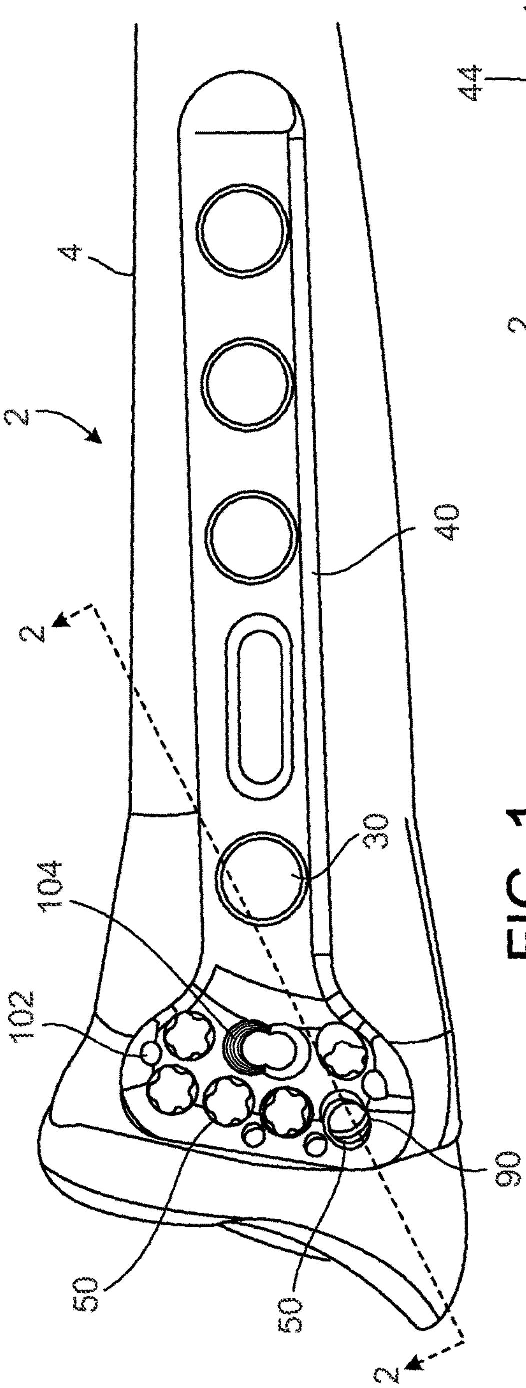

FIG. 1

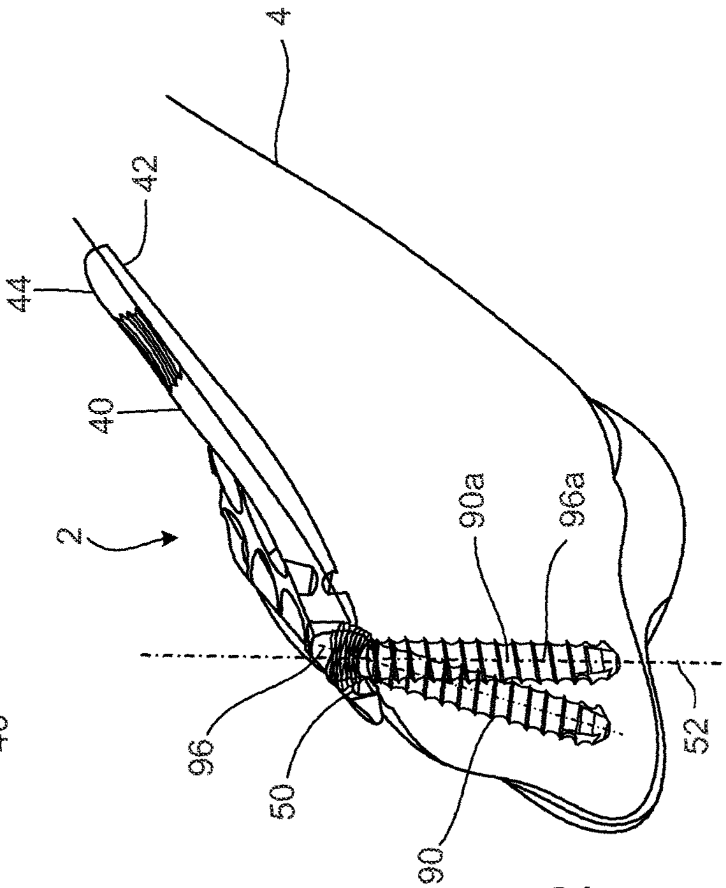

FIG. 2

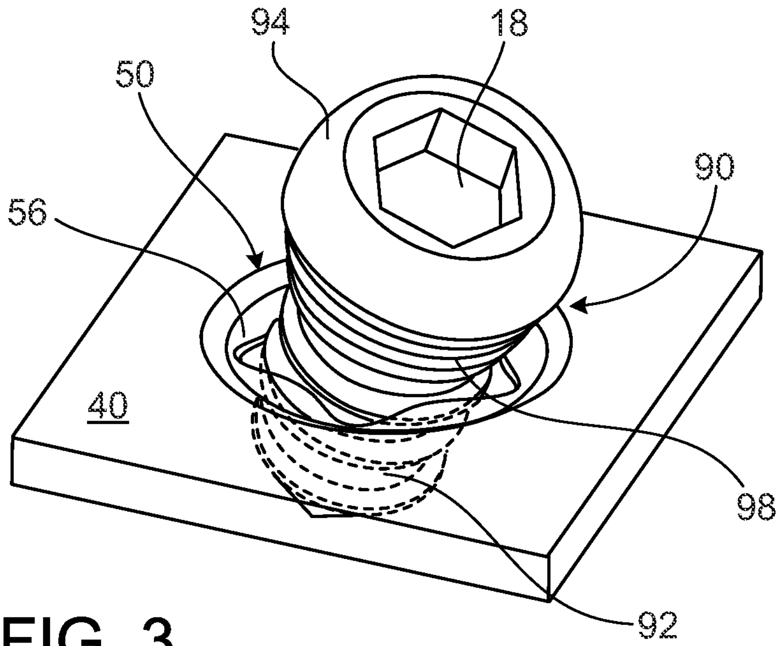

FIG. 3

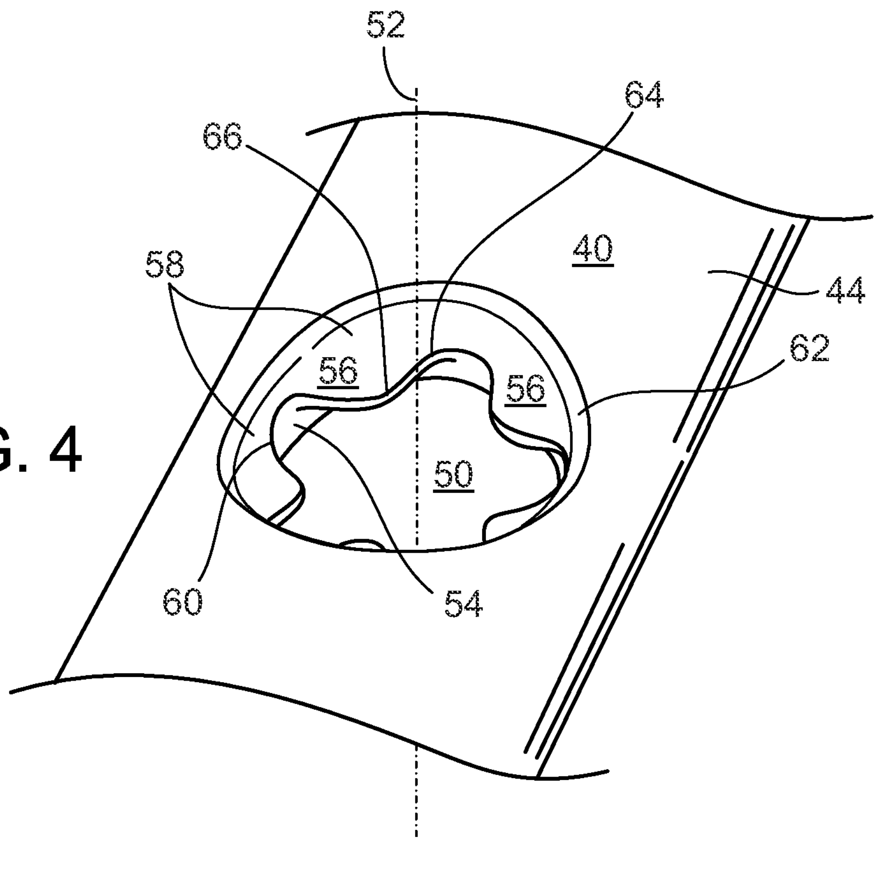

FIG. 4

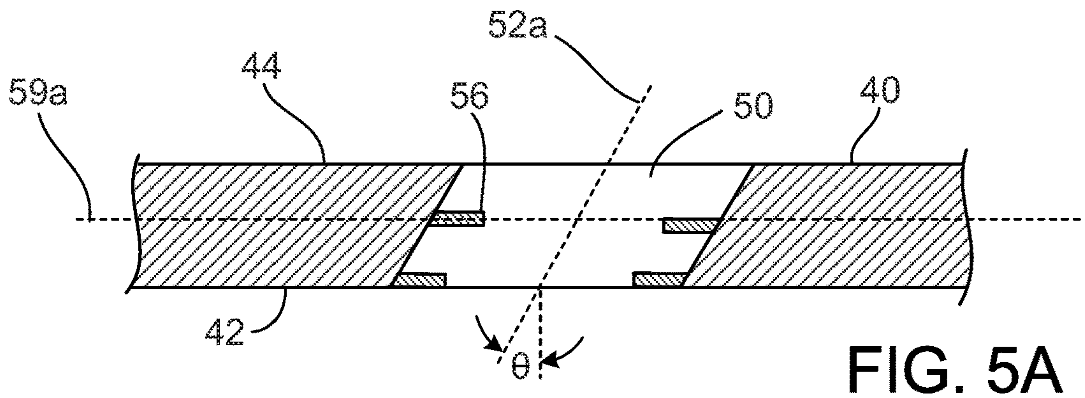

FIG. 5A

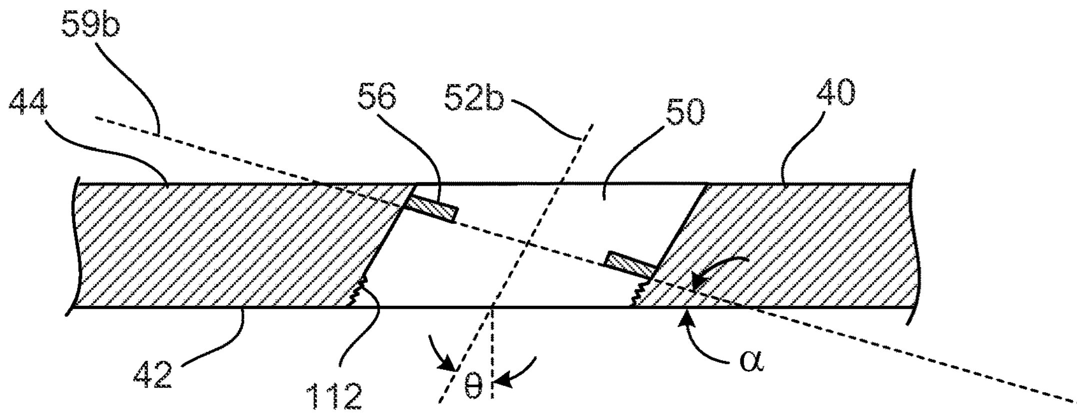

FIG. 5B

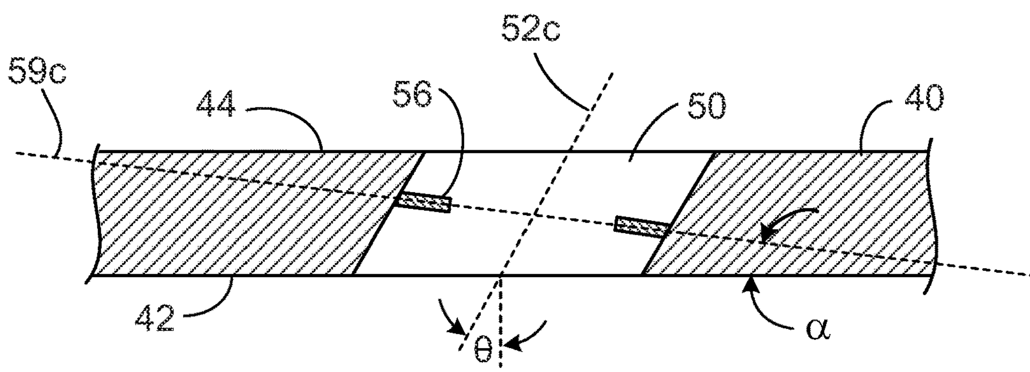

FIG. 5C

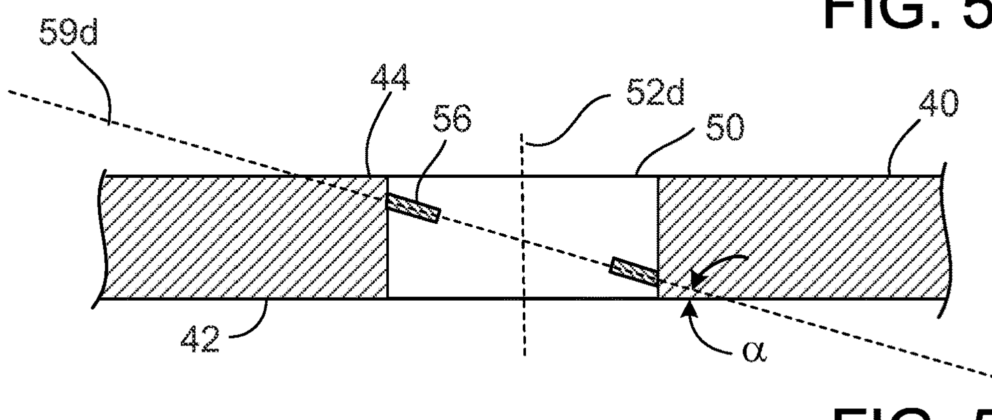

FIG. 5D

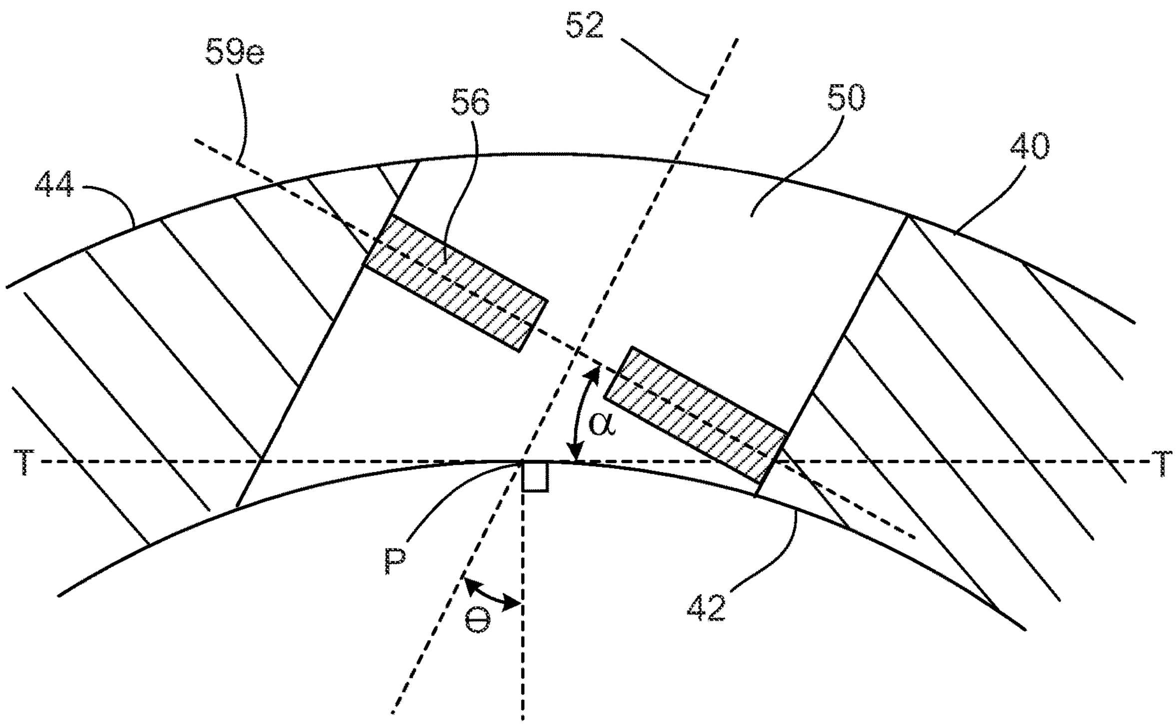

FIG. 5E

VARIABLE ANGLE LOCKING IMPLANT

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation application of U.S. patent application Ser. No. 16/569,204, filed Sep. 12, 2019, entitled "Variable Angle Locking Implant", which is a continuation application of U.S. patent application Ser. No. 15/970,747, filed May 3, 2018, now U.S. Pat. No. 10,448,980, entitled "Variable Angle Locking Implant", which is a continuation application of U.S. patent application Ser. No. 13/524,506, filed Jun. 15, 2012, entitled "Variable Angle Locking Implant", which application claims priority to and the full benefit of U.S. Provisional Application Ser. No. 61/497,180 filed Jun. 15, 2011, and entitled "Variable Angle Locking Implant," the entire contents of each application incorporated herein by reference.

TECHNICAL FIELD

This invention relates to a variable angle locking implant.

BACKGROUND

Variable angle locking implants for repairing bone fractures have been described, for example, in U.S. patent application Ser. No. 12/484,527, filed Jun. 15, 2009, published as U.S. Publication No. 2009/0312803, hereby incorporated herein by reference in its entirety. In particular, U.S. Publication No. 2009/0312803 describes an implant having fastener receiving holes with fins that permit a fastener to be positioned off-axis within the hole.

Implants such as bone plates have been provided with threaded holes (that may receive either locking screws or non-locking screws), non-threaded holes (for non-locking screws), partially threaded slots to allow either non-locking or locking screws to be used together, and combinations of the above.

SUMMARY

The variable angle locking implant provides a stable connection between a bone and a bone plate using a fastener that permits different angles to be obtained between the bone plate and the fastener, while the fastener also locks into the bone plate. This allows the surgeon to reach denser areas of bone or capture random bone fragments that are in irregular positions, for example, in cases of severe fractures with highly fragmented bones. The fastener and plate system advantageously allows the surgeon to choose the angle at which the screw is inserted through, and rigidly affixed in, an opening of the plate.

The variable angle locking implant allows a surgeon to direct the fastener toward bone fragments that are not necessarily located along the axis of the opening in the plate. It also provides flexibility in the placement of the plate in relation to the bone fracture. Allowing surgeons to choose the angle at which the fastener is inserted into the plate leads to better tailoring of the system to the specific nature of the bone fracture to be treated, and allows surgeons to adjust their strategy as necessary after the surgical site has been accessed, but prior to insertion of the fastener into bone material.

According to one aspect, a variable angle locking implant includes a bone plate having a lower surface, an upper surface, and at least one opening extending from the lower surface to the upper surface along an axis. The opening has an inner surface with a plurality of fins oriented along a plane. The axis is non-perpendicular to a tangent of a projection of the lower surface across the opening, the tangent defined at the intersection between the axis and the projected lower surface, and/or the plane is non-parallel to the tangent.

Implementations of this aspect may include one or more of the following features.

For example, the lower surface includes a bone conforming arcuate surface. The lower surface is adapted to contact a distal femur, a proximal femur, a distal tibia, a proximal tibia, a proximal humerus, a distal humerus, a clavicle, a fibula, an ulna, a radius, a distal radius, a rib, pelvis, a vertebra, bones of the foot, or bones of the hand, shaft fractures on long bones, or any of the aforementioned adjacent bones in the case of a joint fusion plate.

The fins are positioned within the opening. The axis is perpendicular to the tangent and the plane is non-parallel to the tangent. Alternatively, the axis is non-perpendicular to the tangent and the plane is non-parallel to the tangent, for example, the plane is perpendicular to the axis.

The fins are integrally connected to, and protruding from, the inner surface. The opening has a radius between the inner surface and the top of the fins, and each fin tapers in thickness from the inner surface towards its terminal end. The opening has a jagged circumference formed by protruding fins at the lower surface. The protruding fins form a concave portion of the inner surface. The protruding fins have bases that meet the inner surface along the plane. The fins have a tapered shape or a straight shape. The fins are provided in more than one layer. The fins are trapezoidally-shaped, rounded, oval, rectangular, curved, rhomboid, diamond-shaped, or triangular. The edges of the fins taper inwardly, outwardly, or are about parallel with one another. There are at least 3, but no more than 10, fins integrally connected to, and protruding from, the inner surface. The fins are provided as a series of concavely indented, inwardly protruding fins that are adapted to secure a threaded head of a fastener in place at varying angles.

The bone plate includes one or more of the following openings: a threaded opening; a non-threaded opening; an opening adapted to receive locking or non-locking fasteners; an opening with fins; a provisional fixation opening; a combination slot; or any combination thereof.

The implant includes at least one fastener. The fastener is at least partially threaded and has a head portion and a shaft portion. The opening is adapted to receive the fastener without being tapped by the fastener. The plurality of fins are deflectable relative to the head portion of the fastener when the fastener is inserted into the opening such that the fastener can be inserted and retained at any one of a plurality of angles relative to the opening. The fins are deflectable so that the fins are interposed between the threads of the fastener. The inner surface includes threads located above or below the fins.

According to another aspect, a method for securing a bone plate to a bone includes placing a lower surface of the bone plate against the bone; inserting a fastener into an opening in the bone plate, the opening having an axis that is non-perpendicular to a tangent of a projection of the lower surface across the opening, the tangent defined at the intersection between the axis and the projected lower surface, selecting a trajectory of the fastener into the bone, the trajectory being up to about 15 degrees off the hole axis; and inserting the fastener into the bone.

Implementations of this aspect may include one or more of the following features.

For example, either a locking screw or a non-locking screw is inserted in the opening. The fastener is removed and re-inserted into the opening of the bone plate at any one of a plurality of angles. Inserting the fastener into the bone includes drawing a bone fragment into alignment with an intact bone segment.

The details of one or more implementations of the invention are set forth in the accompanying drawings and the description below. Other features, objects, and advantages of the invention will be apparent from the description and drawings, and from the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is an illustration of a variable angle locking implant positioned on a bone.

FIG. **2** is a cross-sectional view of the variable angle locking implant taken along line **2-2** of FIG. **1**.

FIG. **3** is a perspective view of a bone plate and fastener of the variable angle locking implant.

FIG. **4** is a perspective view of a bone plate of the variable angle locking implant having a finned opening.

FIGS. **5**A-**5**E are cross-sectional views of various implementations of the finned opening.

DETAILED DESCRIPTION

Referring to FIGS. **1** and **2**, a variable angle locking implant **2** for repairing fractures in bone **4** includes a bone plate **40** and one or more fasteners **90**. A fastener **90** is shown engaged in a finned opening **50** that extends between an upper surface **44** and a lower, bone contacting surface **42** of the bone plate **40**. The fastener **90** can be positioned in the opening **50** and fixed in the plate **40** at various insertion angles to capture "renegade" or random bone fragments that have split from the bone during fracture and secure the bone fragments to the plate **40**.

The fastener **90** shows a new trajectory achieved by increasing the range of angles as compared to the screw **90***a*. For example, the central axis **96** of fastener **90** has an approximate 15 degree offset from the central axis **52** and approximately 30 degree offset from perpendicular to the lower surface **42** of the bone plate **40**. The alternative placement of a screw **90***a* in a hole having an axis **52** perpendicular to the lower surface **42** of the plate **40** and a plane **59** that is parallel to the bottom lower surface **42** illustrates approximately a 15 degree offset from the central axis **52** and a corresponding approximately 15 degree offset from perpendicular to the lower surface **42** of the bone plate **40**, thus illustrating the greater range of the insertion angle of the fastener **90**.

The locking implant **2** also includes a provisional pin opening **102** as well as a combination slot **104**.

Referring also to FIGS. **3** and **4**, the plate **40** has an inner surface **54** that defines the opening **50** and a series of concavely indented, inwardly protruding fins **56** that extend toward a central axis **52** of the opening **50**. Each fin **56** has a base **58** and the bases **58** form concave portions **60**. The bases **58** of the fins **56** all meet, for example, in substantially the same plane **59***a*-**59***d* (FIGS. **5**A-**5**D) and then angle downwardly and inwardly at a similar angle or slope. As discussed further below, the central axis **52** can be oriented non-perpendicular to the lower surface **42** and/or the planes **59***a*-**59***d* can be oriented non-parallel to the lower surface **42** to increase the range of possible insertion angles.

The concave portions **60** are smooth and non-threaded, and as illustrated, the entire inner surface **54** of the finned opening **50** can be devoid of threads. The lack of threads helps ease the manufacturing of the plate **40**, and allows the plate **40** to be manufactured as thinly as desired. The bases **58** can extend from the inner surface **54** at or near an upper circumference **62** of the inner surface, at a middle region of the inner surface, or at or near a lower circumference of the inner surface. With the fins **56** located adjacent a lower circumference at the lower, bone contacting surface **42** of plate **40**, the lower circumference appears jagged due to the presence of the fins, while the upper circumference **62** is smooth.

As the fins **56** extend toward central axis **52**, they taper to form tapered sides **64**. The fins **56** end at rounded tips **66**, although tips **66** can be pointed, square, rectangular, or any other appropriate configuration. For example, as described in U.S. Patent Application Publication No. 2009/0312803, which is incorporated herein by reference in its entirety, the fins **56** can have straight edges or sides and straight ends such that the fins are partially rectangular-shaped with slit-shaped openings between the fins. Alternatively, the fins can be more triangular in shape having sides that taper inwardly and end edges that are flat and small. Other example fin shapes include trapezoidal, square, round, circular, triangular (with a pointed tip).

The dimensions of fins **56** are typically dependent at least in part upon the pitch and threads of the fastener **90**. For example, a larger plate **40** for use with a larger fastener **90** (for example, for use on a femur bone) will likely be thicker and will have larger and thicker fins **56** than a smaller plate **40** (for example, for use on a smaller bone). In specific implementations, the fins **56** are particularly thin so that they can be moved up or down and deformed under pressure. In some implementations, the fins **56** may be pressed toward the edges of the finned opening **50**. A non-limiting exemplary range of thicknesses for the fins **56** is from about 0.15 mm to about 5 mm, although larger and smaller sizes are possible. The fins **56** are intended to fit between threads **98** on the thread form of fastener **90**, as shown in FIG. **3**.

Providing a non-threaded inner surface **54** also allows the fastener **90** to be inserted into the finned opening **50** at any desired insertion angle, that is the angle defined between a longitudinal axis **96** (FIG. **2**) of the fastener **90** and the central axis **52** (FIG. **4**) of the finned opening **50**. The central axis **52** and the longitudinal axis **96** can be co-linear so that the insertion angle is zero, or the central axis **52** and the longitudinal axis **96** (FIG. **1**) can be non-co-linear with an insertion angle of up to about +/−15 degrees. Varying the insertion angle is possible because there are not any threads in the finned opening **50** to interfere with the desired insertion angle. The fins **56** are intended to slightly bend or deform in order to secure the fastener **90** in place in the finned opening **50**. The fins **56** engage the threads **98** or other surface of the fastener **90**.

The fastener **90** has a head **94** and a shaft **92**. The shaft **92** may be threaded or non-threaded. The head **94** of the fastener **90** has at least one set of threads **98** and a bore **18** for receiving a driver in order to drive the fastener **90** through the plate **40** and into bone. The threads **98** are typically any standard-type thread.

Referring to FIGS. **5**A and **5**B, the central axis **52***a*, **52***b* of the opening **50** can be oriented non-perpendicular to the lower surface **42** of the plate **40**, for example, at an angle, Θ, in the range between 0 and 90 degrees. In FIG. **5**A, two rows of fins **56** are illustrated that each lie in a plane **59***a* that is parallel to the lower surface **42** of the plate **40**. In FIG. **5**B, the fins **56** lie in a plane **59***b* that is oriented non-parallel to the lower surface **42** of the plate **40**, for example, the plane **59***b* is perpendicular or nearly perpendicular to the axis **52***b*. In FIG. **5**C, the fins **56** are illustrated lying in a plane **59***c* that is oriented non-parallel to the lower surface **42** of the plate **40** and the plane **59***c* is non-perpendicular to the axis **52***c*. The fins **56** of FIGS. **5**B and **5**C are positioned within the opening **50**, that is, between the upper surface **44** and lower surface **42** of the plate **40**.

The non-perpendicular orientation of the central axis **52***a*, **52***b*, **52***d* and/or the non-parallel orientation of the plane **59***b-d* increases the useful range of possible insertion angles as compared to a bone plate **40** having the central axis **52** perpendicular to the lower surface **42** and the plane **59** parallel to the lower surface **42**. For example, referring to FIG. **5**B, assuming Θ is 15 degrees, a fastener **90** could be inserted with the fastener axis **96** aligned with axis **52***b*, and thus 15 degrees off from perpendicular to the lower surface **42**, or the fastener axis **96** could be tilted up to, for example, +/−15 degrees, such that the fastener axis **96** is perpendicular to the lower surface **42** or up to 30 degrees off from perpendicular to reach bone fragments. Increasing the range of angles allows the surgeon to target new fastener trajectories in the bone as shown in FIG. **2**.

The screw **90** (FIG. **2**) shows a new trajectory achieved by increasing the range of angles as compared to the screw **90***a*. The fastener **90** is shown positioned in the hole of FIG. **5**B and having a 15 degree offset from the central axis **52** and 30 degree offset from perpendicular to the lower surface **42** of the bone plate **40**. The alternative placement of a screw **90***a* in a hole having an axis **52** perpendicular to the lower surface **42** of the plate **40** and a plane **59** that is parallel to the lower surface **42** illustrates a 15 degree offset from the central axis **52** and only a corresponding 15 degree offset from perpendicular to the lower surface **42** of the bone plate **40**, thus illustrating the greater range of the insertion angle of the fastener **90**. Angling the screw greater than 15 degrees from the central axis **52** of an opening having an axis **52** perpendicular to the lower surface **42** of the plate **40** and a plane **59** that is parallel to the lower surface **42** produces inconsistent failure loads. Therefore, to achieve a screw trajectory greater than 15 degrees from the lower surface **42** of the plate **40** while maintaining the ability to capture and secure bone fragments, the angle of the central axis **52** is offset from perpendicular to the lower surface **42** and the screw axis **96** tilted to reach a maximum of 30 degrees offset.

Referring to FIG. **5**D, the range of insertion angles can also be increased by orienting the axis **52***d* of the opening **50** perpendicular to the lower surface **42** of the plate **40**, while the fins **56** lie in a plane **59***d* that is non-parallel to the lower surface, for example, at an angle, α, in the range between 0 and 90 degrees.

The finned opening **50** can include about five to eight fins **56**, as illustrated, two or three fins **56**, or ten or twenty or more fins **56**, depending upon the plate **40** for which the finned opening **50** is intended for use. The finned holes can optionally include threads **112** (FIG. **5**B) formed above or below the fins in the inner surface of the hole. The region of the opening above the fins can taper inwardly from the upper surface of the plate, for example, at an angle of about 5 to 15 degrees, and the region of the opening below the fins can taper outwardly toward the lower surface of the plate, for example, at an angle of about 40 to 50 degrees. The finned opening **50** can optionally be a slot hole or combination hole with half or more of the length of the opening can be finned with the remainder of the opening being non-threaded for sliding compression.

The primary purpose of fins **56** is to grasp one or more threads **98** of the fastener **90** in order to secure the fastener **90** in place in the bone plate **40** at any desired insertion angle. Fasteners **90** received in different finned openings **50** can be inserted at the same or different insertion angles. As a fastener **90** is inserted, its threads **98** start to engage the fins **56**, as shown in FIG. **3**. As discussed above, the fins **56** can be very thin so that as the threads **98** start to grab the fins **56**, the fins **56** can move up or down as appropriate to engage the threads **98** and secure the fastener **90** in the finned opening **50**. The threads **98** engage the fins **56** so that the fins **56** fit between the threads **98**. The movement of fins **56** can be a permanent deformation, so that the fins **56** cannot flex back and allow the fastener **90** to work its way out.

The finned openings **50** can be provided on all types of bone plates **40** and can be combined with other types of openings. As illustrated in FIG. **1**, there can be finned openings **50**, a threaded opening **30**, and a provisional pin opening **102**. Other options are holes that can be used with either a threaded or non-threaded fastener, as well as combination slots **104**. For example, a slot having fins mounted on either or both ends of the slot for static locking and no threads or fins in the middle portion of the slot for dynamic locking These various types of openings may be used on any type of bone plate, in any combination and in any size. The inclusion of a plurality of finned openings **50** in the bone plate **40** can help achieve better fixation of a fractured bone, for example, where numerous fragments have shattered in various directions, because the fasteners **90** can be inserted at various angles to capture "renegade" or random bone fragments that have split from the bone during fracture, but still secure the bone fragments to the plate **40**.

The threads **98** on fastener **90** can be any type of standard or non-standard thread. For example, the threads **98** can be a continuous ridge or a non-continuous ridge. The threads **98** can form a portion of a revolution, one complete revolution, multiple revolutions, a single lead, or multiple leads, or any other threads known in the art. Additionally or alternatively, the head **94** of fastener **90** can include any other surface that will engage with and seat within the fins **56** of the finned opening **50**. For example, the head **94** can have a series of dimples, ridges, bumps, textured areas, or any other surface that can secure fastener **90**.

The fastener **90** may be any typical fastener, made out of any appropriate material. The fastener **90** typically has a bore **18** for receiving a driver in order to drive the fastener **90** through the plate **40** and into bone. The bore **18** may be any size and shape, for example, it may have a hexagonal configuration to receive a corresponding hexagonal driver, a Phillips screw head, a flat-head, a star configuration, Torx, or any other appropriate configuration that can cooperate with a driver to drive the fastener **90** into the plate **40**.

The shaft **92** may be fully threaded, partially threaded, or a helical blade, and/or may include one or more tacks, deployable talons, expandable elements, or any feature that allows shaft **92** to engage bone. It is also possible that shaft **92** is not threaded, so that fastener **90** takes the form of a peg or a pin. This alternative implementation may be preferred in certain procedures where, for instance, the main goal is to prevent tilting of a bone segment or in procedures where there is no concern of fastener **90** pulling out from the bone and hence no need for shaft **92** to be threaded or otherwise configured to engage bone. The end of shaft **92** may be a self-tapping or self-drilling tip.

The bone plate **40** may be adapted to contact one or more of a distal femur, a proximal femur, a distal tibia, a proximal tibia, a proximal humerus, a distal humerus, a clavicle, a fibula, an ulna, a radius, a distal radius, a rib, pelvis, a vertebra, bones of the foot, or bones of the hand, shaft fractures on long bones, or any of the aforementioned adjacent bones in the case of a joint fusion plate. The bone plate **40** may be curved, contoured, straight, or flat. The lower, bone contacting surface **42** can have an arcuate shape that conforms to the bone. For example, referring to FIG. **5**E, the bone plate **40** is shown with a bone contacting surface **42** having an arcuate or curved shape. In the implementation shown, the central axis **52** of the opening **50** can be oriented non-perpendicular to a tangent line or tangent plane T-T of the projected arcuate bone contacting surface **42** that intersects the central axis **52** at a point P along the projected bone contacting surface **42**, for example, at an angle, Θ, in the range of between 0 and 90 degrees. In FIG. **5**E, a row of fins **56** is illustrated that each lie in a plane **59***e* that is oriented non-parallel to the tangent line or plane T-T. The fins **56** can alternatively be located at the lower surface **42** and also have an arcuate shape that conforms to the bone. The plate can be a periarticular plate or a straight plate. The plate may have a head portion that is contoured to conform to a particular bone surface, such as a metaphysis or diaphysis, that flares out from the shaft portion, that forms an L-shape, T-shape, Y-shape, with the shaft portion, or that forms any other appropriate shape to fit the bone to be treated.

The bone plate **40** can be made from metal, a resorbable or non-resorbable plastic, ceramic, or composite materials. Suitable materials may include, for example, titanium, stainless steel, cobalt chrome, polyetheretherketone (PEEK), polyethylene, ultra high molecular weight polyethylene (UHMWPE), resorbable polylactic acid (PLA), polyglycolic acid (PGA), combinations or alloys of such materials or any other appropriate material that has sufficient strength to be secured to and hold bone, while also having sufficient biocompatibility to be implanted into a body.

Turning now to the methods of implantation, the surgeon accesses the surgical site of interest, which can be an internal site at which a bone fracture is located that requires stabilization to ensure proper healing. The fracture may be reduced with conventional forceps and guides (which are known to those in the art), and a bone plate **40** of appropriate size and shape is placed over the fracture site. In some instances, the bone plate **40** may be temporarily secured to the bone **4** using provisional fixation pins. The provisional fixation pins may be used through either the provisional pin openings **102**, or any other opening in the plate **40**. Provisional fixation provides for temporarily securing the bone plate **40** to the bone **4** before placing fixation screws through the bone plate **40**, so that one can be certain the bone plate **40** is properly positioned before placing bone screws for permanent fixation of the bone plate **40** to the bone **4**. Moreover, with provisional fixation, x-rays can be taken of the bone plate/construct without excess instruments in the field of view.

Once the plate **40** is secured at a desired location in relation to the fracture (typically using one or more provisional fixation pins, although any other appropriate method may be used), the surgeon then identifies an insertion angle at which the fastener **90** is to be inserted through a selected opening **50** and driven into bone material **4**. If the bone plate **40** includes more than one opening **50**, the surgeon also selects the specific opening **50** to be used. After selecting the desired insertion angle and the opening **50**, the surgeon inserts the shaft **92** of the fastener **90** through the opening **50** until the tip contacts bone material **4**. In some cases, a hole may need to be drilled or tapped into the bone **4** along the insertion angle to facilitate the initial tapping or insertion of the fastener **90**. The surgeon then uses an appropriate driving tool in the bore **18** of the head **94** to manipulate the fastener **90** into place.

Because the fastener **90** can be inserted at angles up to about 60 degrees from perpendicular to the lower surface of the plate, the fastener **90** can be used to grab and/or secure bone fragments that are out of line with the traditional angle at which a locking screw would normally be inserted. The surgeon may need to toggle or maneuver the fastener **90** in order to secure and draw in displaced bone fragments.

Once the bone fragment is secured, the fastener **90** is ready to be secured to the plate **40**. As the fastener **90** is driven further into bone **4**, it is also drawn further into the plate **40**. As the threads **98** of the fastener head **94** begin to contact the fins **56**, the fins **56** engage within the threads **98** to hold the fastener **90** in place at the desired insertion angle. The action of engagement between the fins **56** and the threads **98** rigidly affixes the fastener **90** to the bone plate **40** at the desired insertion angle.

The surgeon may then use traditional locking and/or non-locking screws in other openings on the plate **40**. This can help further secure the bone plate **40** to the bone fracture if needed.

Once all the fasteners and/or screws are placed, the surgeon may place covers over the unused openings, particularly if there are any unused openings that cross the fracture, to strengthen the plate **40**. Additionally or alternatively, the surgeon may use bone graft material, bone cement, bone void filler, and any other material to help heal the bone.

In practice, a first screw is initially inserted through a bone plate **40** and into a bone **4** on one side of a fracture and then a second screw is inserted through the bone plate **40** on the opposite side of the fracture. In particular, after the first screw is in place, an axial compression screw is inserted through a hole in the bone plate **40** on a side of the fracture opposite the side of the first screw. The compression screw may be inserted through the hole and into the bone **4** such that as the compression screw is fully inserted, the bone plate **40** is drawn over to a desired position. By moving the bone plate **40**, the tissue is pulled together to reduce the fracture. Once the compression screw has been used to move the bone plate **40** into the desired position, the compression screw may be removed from the bone **4** and bone plate **40** and a locking screw may be inserted through the opening **50** in the bone plate **40** and in the bone **4** in the space formerly occupied by the compression screw. The locking screw can then be tightened to lock the plate **40** into position. The replacement of the compression screw with the locking screw is not required, but a locking screw may provide more stability and rigid fixation than leaving the compression screw in place. In some modes of operation, a locking screw is placed directly in a locking hole without first inserting a compression screw in the hole.

A number of implementations of the invention have been described. Nevertheless, it will be understood that various modifications may be made without departing from the spirit and scope of the invention. Accordingly, other implementations are within the scope of the following claims. For example, locking screws, non-locking screws, or other fasteners may be used. One or more openings having a non-perpendicular orientation of the central axis **52** and/or the non-parallel orientation of the plane **59** can be employed to receive a fastener in implants other than plates, such as in an acetabular cup or glenoid base component, to increase the useful range of possible insertion angles of the fastener. According to another implementation, the head of the screw

94 can include the fins **56** and the opening **50** can be threaded, with the opening having a non-perpendicular orientation of its central axis **52** and/or the plane **59** defined by the fins **56** having a non-parallel orientation.

What is claimed is:

1. An implant comprising:
a first surface;
a second surface; and
at least one opening extending from the first surface to the second surface, the at least one opening including:
a central axis;
an inner surface including a plurality of fins defining a circumferential edge to contact a head of a bone fastener in use; and
a plurality of threads formed on the inner surface;
wherein the at least one opening is configured to secure the bone fastener with respect to the implant.

2. The implant of claim **1**, wherein the central axis is non-perpendicular to a tangent of a projection of the first surface across the opening, the tangent defined at an intersection between the central axis and the projected first surface.

3. The implant of claim **2**, wherein the plurality of fins are oriented along a plane, wherein each of the fins has a base and a tip, wherein each of the fins extends through the plane from the base to the tip, and wherein the tip of each fin has a rounded, convex curve that lies in the plane.

4. The implant of claim **3**, wherein the plane along which the plurality of fins is oriented is nonparallel to the tangent.

5. The implant of claim **4**, wherein the plane is perpendicular to the central axis.

6. The implant of claim **1**, wherein the plurality of fins are adapted and configured to deform in order to secure a position of the head of the bone fastener inserted into the at least one opening.

7. The implant of claim **1**, wherein the implant is a bone plate, the first surface is a bone contacting surface, and the plurality of threads are positioned closer to the bone contacting surface than the plurality of fins.

8. The implant of claim **7**, wherein the bone contacting surface is adapted to contact a distal femur, a proximal femur, a distal tibia, a proximal tibia, a proximal humerus, a distal humerus, a clavicle, a fibula, an ulna, a radius, a distal radius, a rib, pelvis, a vertebra, bones of a foot, or bones of a hand.

9. The implant of claim **7**, wherein the central axis is non-perpendicular to the bone contacting surface, the plurality of fins are oriented along a plane, wherein the plane is oriented nonparallel to the bone contacting surface.

10. The implant of claim **9**, wherein the central axis is orientated an angle relative to the bone contacting surface, the angle being fifteen degrees.

11. The implant of claim **1**, wherein each of the plurality of fins includes a tip having a rounded, convex curve, each of the plurality of fins extends toward the central axis of the opening from a base to the rounded, convex curve, and each of the plurality of fins has a width in the plane that decreases from the base to the tip in a direction toward the central axis of the opening.

12. The implant of claim **1**, wherein the implant has at least 3, but no more than 10, fins integrally connected to, and protruding from, the inner surface.

13. The implant of claim **1**, wherein the plurality of fins are provided as a series of inwardly protruding fins that are adapted to secure the head of the bone fastener in place at varying angles, wherein the head is threaded, wherein adjacent fins in the series of inwardly protruding fins cooperate to form a curved, concave indentation along the plane.

14. The implant of claim **1**, wherein the opening is adapted to receive the bone fastener without being tapped by the bone fastener, wherein the plurality of fins are deflectable relative to the head of the bone fastener when the bone fastener is inserted into the opening such that the bone fastener can be inserted and retained at any one of a plurality of angles relative to the opening.

15. The implant of claim **14**, wherein the plurality of fins are deflectable so that the plurality fins are interposed between threads of the bone fastener.

16. A variable angle locking implant comprising:
a bone plate having:
an end portion;
a shaft portion that extends along a longitudinal axis;
a lower bone contacting surface;
an upper surface; and
an opening including:
a central axis, the opening extending along the central axis from the lower bone contacting surface to the upper surface;
an inner surface including a plurality of fins oriented along a plane, wherein each of the fins has a base and a tip, wherein each of the fins extends through the plane from the base to the tip, the tips of the plurality of fins collectively defining a circumferential edge to contact a head of a bone fastener in use; and
a plurality of threads formed on the inner surface.

17. The variable angle locking implant of claim **16**, wherein the central axis is non-perpendicular to the lower bone contacting surface and the plane is oriented nonparallel to the lower bone contacting surface.

18. The variable angle locking implant of claim **16**, wherein the plurality of threads are positioned closer to the lower bone contacting surface than the plurality of fins.

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