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## Patent Public Search | Text View

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United States Patent Application Publication

20250255621

Kind Code

A1

Publication Date

August 14, 2025

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## SYSTEMS AND METHODS FOR INTRAMEDULLARY NAIL IMPLANTATION

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### Abstract

Intramedullary nails, systems, and methods. The intramedullary nail may include a generally elongate body extending from a first, distal end to a second, proximal end. The distal end may include one or more openings configured to receive one or more bone anchors that extend transversely through the distal end of the intramedullary nail, and thereby configured to secure the distal end of the nail. The proximal end may also include one or more openings configured to receive one or more bone anchors that extend transversely through the proximal end of the intramedullary nail, and thereby configured to secure the proximal end of the nail.

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**Family ID:** 62144557

**Appl. No.:** 19/192615

**Filed:** April 29, 2025

### Related U.S. Application Data

parent US continuation 17968337 20221018 parent-grant-document US 12285178 child US 19192615

parent US continuation 16670472 20191031 parent-grant-document US 11490905 child US 17968337

parent US continuation 15862687 20180105 parent-grant-document US 10492803 child US 16670472

parent US continuation-in-part 15441457 20170224 parent-grant-document US 10307197 child US 15862687

parent US continuation-in-part 15423773 20170203 parent-grant-document US 10251691 child US 15441457

## Publication Classification

**Int. Cl.:** A61B17/17 (20060101); A61B17/16 (20060101); A61B17/72 (20060101)

**U.S. Cl.:**

**CPC** A61B17/1717 (20130101); A61B17/1615 (20130101); A61B17/1725 (20130101);  
A61B17/72 (20130101); A61B17/7233 (20130101);

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## Background/Summary

CROSS REFERENCE TO RELATED APPLICATION [0001] This application is a continuation of U.S. application Ser. No. 17/968,337, filed on Oct. 18, 2022, which is a continuation of U.S. application Ser. No. 16/670,472, filed on Oct. 31, 2019 (published as U.S. 2020-069318), which is a continuation of U.S. application Ser. No. 15/862,687, filed Jan. 5, 2018, now U.S. Pat. No. 10,492,803, which (i) is a continuation-in-part of U.S. application Ser. No. 15/441,457, filed Feb. 24, 2017, now U.S. Pat. No. 10,307,197, which is a continuation-in-part of U.S. application Ser. No. 15/423,773, filed on Feb. 3, 2017, now U.S. Pat. No. 10,251,691, which is a continuation-in-part of U.S. application Ser. No. 15/272,850, filed on Sep. 22, 2016, now U.S. Pat. No. 10,299,847; and (ii) claims the benefit of U.S. Provisional Application Ser. No. 62/569,763, filed on Oct. 9, 2017 (expired). The contents of each of these applications are incorporated herein by reference in their entirety for all purposes.

### TECHNICAL FIELD

[0002] The present technology is generally related to intramedullary nail implantation for treatment of bone fractures. In particular, several embodiments are directed to systems and methods for implanting an intramedullary nail for immobilizing bone fractures.

### BACKGROUND

[0003] The significant long bones of the extremities are the humerus, radius and ulna of the upper extremity and the femur and tibia of the lower extremity. Following an injury to the long bone, and in particular, injuries resulting in one or more fractures of the long bone, one or more fixation devices may be used to immobilize the fracture fragments and stabilize the long bone. Bone fractures can be treated with screws or other fixation devices inserted into or through the bone to stabilize it once the fractured portions have been brought into proper alignment. Femoral neck fixation, for example, can be used to treat hip fractures by inserting an intramedullary nail into the medullary cavity of the fractured femur followed by insertion of a fixation screw into the femoral neck/head at an angle relative to the intramedullary nail. Similarly, other long bone fractures can be treated by inserting an intramedullary nail into the intramedullary canal of the bone and providing the appropriate proximal and/or distal fixation. Traditional intramedullary devices may suffer from a number of disadvantages, however. For example, they may be susceptible to implant failure and difficulty in alignment of the fixation screw with respect to the intramedullary nail. Accordingly, there is a need for improved systems and methods for intramedullary nail implantation.

### SUMMARY

[0004] Intramedullary nails, systems, insertion tools, and method of treatment are provided. The intramedullary nails may be suitable for implanting within a medullary canal of a fractured long

bone and subsequently providing proximal fixation and/or distal fixation, for example, with one or more anchors, fasteners, fixation screws, or the like. Suitable long bones may include the humerus, radius, ulna, femur, tibia, or the like. Although generally described with reference to the femur and tibia, it will be appreciated that the intramedullary nail and system may be adapted for use with any long bone.

[0005] According to one aspect, an intramedullary nail is provided. The intramedullary nail may comprise a generally elongate body extending from a first, distal end to a second, proximal end. The distal end may include one or more openings configured to receive one or more bone anchors or fasteners that extend transversely through the distal end intramedullary nail, and thereby configured to secure the distal end of the nail. The proximal end may also include one or more openings configured to receive one or more bone anchors or fasteners that extend transversely through the proximal end of the intramedullary nail, and thereby configured to secure the proximal end of the nail.

[0006] In accordance with another aspect, a system for inserting an intramedullary nail into a bone is provided. The system includes an intramedullary nail having a proximal end, a distal end, at least one side surface extending between the proximal end and the distal end, and an aperture through the intramedullary nail. An insertion tool includes a handle portion, a coupling portion and an aiming guide. The handle portion defines a first connection assembly. The coupling portion extends from the handle portion and is configured to removably couple to the proximal end of the intramedullary nail. The aiming guide has a body with at least one support block and a second connection assembly. The first and second connection assemblies are configured to releasably interconnect the handle portion and the aiming guide. The at least one guide block defines a guide sheath hole configured to receive a guide sheath therethrough. The guide sheath hole is positioned such that, when the intramedullary nail is coupled to the coupling portion, the guide sheath hole substantially aligns with the aperture in the intramedullary nail.

[0007] In accordance with another aspect, an intramedullary nail system is provided. The system includes an intramedullary nail having a body extending between a proximal end and a distal end with a substantial portion of the body elongated along a first axis. The body has a proximal portion and a distal portion. A first opening is formed through the proximal portion of the body and a second opening is formed through the distal portion of the body. At least the first and second openings are formed with a two-start thread.

[0008] In accordance with another aspect, a system for inserting an intramedullary nail into a bone is provided. The system includes an intramedullary nail having a body which defines a proximal portion and a distal portion, with at least first and second openings defined through the proximal portion of the body. An insertion tool includes an aiming guide having an arcuate body defining at least two hole openings therethrough. Each of the hole openings is axially aligned with a respective one of the first and second openings and configured to receive a guide sheath therethrough. A friction retention assembly is associated with each hole opening and includes a friction pad which retractably extends into the hole opening to engage a guide sheath positioned therein.

[0009] In accordance with another aspect, a cannula system for inserting an intramedullary nail into a bone is described. The cannula system includes a cannula assembly and a drill sleeve. The cannula assembly includes a flexible cannula extending from a rigid handle with a through passage extending through the flexible cannula and the rigid handle. The flexible cannula and the rigid handle further define axial pin slots extending adjacent to the through passage. The drill sleeve includes a sleeve portion configured to be received in the flexible cannula. A housing portion from which the sleeve portion extends is configured such that a portion thereof is received in the through passage within the rigid handle. A pair of release triggers are hingedly connected to the housing portion. Each release trigger defines at least one projection configured to releasably engage within the rigid handle to lock the drill sleeve relative to the cannula assembly. Each of the release triggers further defines a guide area which aligns with a respective axial pin slot such that a fixation pin

may be passed past the housing portion and through the axial pin slot.

[0010] Also provided are kits including intramedullary nails of varying shapes and sizes, bone anchors, fasteners, insertion tools, and components for installing the same.

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## Description

### BRIEF DESCRIPTION OF THE DRAWINGS

[0011] A more complete understanding of the present invention, and the attendant advantages and features thereof, will be more readily understood by reference to the following detailed description when considered in conjunction with the accompanying drawings wherein:

[0012] FIGS. 1-4 illustrate various views of illustrative tibial nails.

[0013] FIGS. 5-12 illustrate various views of illustrative insertion systems.

[0014] FIGS. 13-30 illustrate various views of illustrative cannula systems and illustrative drill sleeves.

### DETAILED DESCRIPTION

[0015] Intramedullary nails, systems, insertion tools, and method of treatment are provided. The intramedullary nails may be suitable for implantation within the intramedullary canal of a fractured long bone and subsequently providing proximal fixation and/or distal fixation, for example, with one or more anchors, fasteners, fixation screws, or the like. Suitable long bones may include the humerus, radius, ulna, femur, tibia, or the like. Although further described with reference to hip fractures of the femur or fractures of the tibia, it will be appreciated that the intramedullary nail and system may be adapted for use with any long bone.

[0016] In conventional hip fracture fixation techniques, there are four main failure modes: axial cutout, cephalad cutout, proximal fragment rotation, and nonunion. "Cutout" is the term for hip screw subsidence into the articular surface of the hip. Cutout can occur in either a cephalad (toward the head) or axial direction (along the axis of the hip screw). Axial cutout is the result of an implant with a small axial profile that provides little resistance to axial translation. Axial cutout can be addressed by the "controlled collapse" features on certain modern hip fracture nails; the hip screw is allowed to translate through the nail, even after the set screw is locked in place. Cephalad cutout is the radial translation of the nail which is the result of a narrow implant that "windshield wipers" through the weak cancellous bone in the hip. Proximal fragment rotation is the result of a circular profile hip screw that acts as a fulcrum to the proximal hip fragment. Fracture nonunion is the result of biologic or mechanical factors that are incompatible with the bone healing process.

Biologic factors of the patient are not controllable by the implant. Mechanical factors are those that typically allow fixation that is too rigid or too flexible. Nonunion is usually the precursor to one of the other three failure modes. Occasionally, nonunion will cause the nail to break in fatigue before the bone fails.

[0017] The intramedullary nails and systems described herein may address one or more of these failure modes. In some embodiments, the intramedullary nail includes proximal and distal locking, for example, to prevent cutout. In other embodiments, the intramedullary nail may include proximal locking including two interlocking fixation devices (e.g., screws), for example, by providing converging and diverging purchase, along with bony fixation in the calcar of the femur, which is the strongest portion of the hip bone. Accordingly, the risk of failure due to cutout and/or rotation can be reduced.

[0018] Additionally, some intramedullary nail implantation systems fail to adequately address the problems of fragment rotation during implantation. Rotation occurs when fragments of the bone rotate about the axis of the screw during the implantation procedure. Conventional anti-rotation technologies require the use of additional instruments or are limited to a single wire placement. In some embodiments, an insertion tool is directly coupled to the intramedullary nail and additional

instruments are not needed for the placement of an anti-rotation guide wire and allow the user to place one or more guide wires anterior and/or posterior to the nail. These guide wires can be positioned to prevent the distal fragments of the femoral head and neck from rotating about the axis of the anchor during the procedure.

[0019] Some systems may be susceptible to backout during the implantation procedure. Backout occurs when the guide sheath used to insert the screw through the intramedullary nail moves proximally away from the bone. Conventional systems either have no features to prevent backout or else provide backout prevention measures that obstruct the normal positioning of the hands during the procedure, resulting in the risk of releasing the guide sheaths and dropping them to the floor. Ratchets on the insertion tool may have the release button facing towards the grip portion on the insertion tool and may present the danger of the user's hand slipping and inadvertently pressing the button. Accidentally pressing the button could result in releasing the sheath and causing the sheath to fall on the floor. In some embodiments, a backout prevention system (e.g., a friction system) may be disposed within the insertion tool, which allows a user to have a hand placed on the grip of the insertion tool without the risk of inadvertently pressing the ratchet release button.

[0020] Although many of the embodiments are described below with respect to devices, systems, and methods for implantation of intramedullary nails, other embodiments are within the scope of the present technology. Additionally, other embodiments of the present technology can have different configurations, components, and/or procedures than those described herein. For example, other embodiments can include additional elements and features beyond those described herein, or other embodiments may not include several of the elements and features shown and described herein.

[0021] For ease of reference, throughout this disclosure identical reference numbers are used to identify similar or analogous components or features, but the use of the same reference number does not imply that the parts should be construed to be identical. Indeed, in many examples described herein, the identically numbered parts are distinct in structure and/or function.

[0022] Referring to FIGS. 1-4, an illustrative tibial intramedullary nail **500** will be described. It is recognized that the features of the nail **500** are not limited to use in a tibial nail and may be incorporated into other intramedullary nails. The intramedullary nail **500** generally comprises an elongate body **502** extending from a first, distal portion or end **503** to a second, proximal portion or end **501**. The elongate body **502** may be in the form of an elongate tubular rod configured to extend longitudinally within the intramedullary canal of a fractured bone. The elongate rod may be hollow or may be solid along its length. The elongate body may be substantially straight along a longitudinal axis of the nail **500** or may comprise one or more curves or bends to conform to the anatomical shape of the intramedullary canal. In the embodiment of the nail **500** illustrated in FIGS. 1-4, the nail **500** is utilized in a tibia and the proximal end has a bend  $\lambda$  relative to the shaft while the distal end has a bend  $\chi$  relative to the shaft. In the illustrated embodiment, the bend  $\lambda$  is approximately  $10^\circ$  while the distal end bend  $\chi$  is approximately  $3^\circ$ . The bends  $\lambda$  and  $\chi$  are not limited to the described angles and may have larger or smaller bends depending on the anatomy of the bone.

[0023] The intramedullary nail **500** may be comprised of any suitable biocompatible materials. The intramedullary nail **500** may be comprised of titanium, cobalt chrome, cobalt-chrome-molybdenum, stainless steel, tungsten carbide, carbon composite, plastic or polymer—such as polyetheretherketone (PEEK), polyethylene, ultra-high molecular weight polyethylene (UHMWPE), resorbable polylactic acid (PLA), polyglycolic acid (PGA), combinations or alloys of such materials, or other appropriate biocompatible materials that have sufficient strength to secure and hold bone, while also having sufficient biocompatibility to be implanted into a body.

[0024] The distal end **503** of the tibial nail **500** contains four openings **510-513**. The openings **510**, **512** are oriented in the AP direction and the openings **511**, **513** are oriented in the ML direction. In the illustrated embodiment, the AP opening **510** and the ML opening **511** each include a two-start

thread **514** used to create a fixed angle construct with the locking screw. Fixed angle constructs are used to treat highly unstable fractures. In unstable fractures or in patients with poor bone quality, it is imperative that the surgeon has an ability to stabilize the lateral translation of the nail relative to the screw. This is often referred to as an interference fit. To achieve interference fit with a locking screw, the threaded holes **510**, **511** includes threads **514** with a two-start thread. In the illustrated embodiment, the threads **514** provide a two start 60-degree machine thread. The threads **514** will have the same pitch as the threads of the screw and the screw shaft preferably also has a two-start thread for easy advancement. The threaded two-start holes **510**, **511** in the nail **500** itself is an advantage over current interference holes because it is easy to manufacture, and requires no additional steps or special techniques on the part of the surgeon. In the illustrated embodiment, the most distal opening **510** is located 5 mm from the distal end of the nail **500**, the next opening **511** is located 15 mm from the distal end, the next opening **512** is located 25 mm from the distal end, and the opening **513** is located 35 mm from the distal end. The opening locations are not limited to the described distances and may be positioned at different locations depending on the anatomy of the bone.

[0025] Returning to FIGS. **1** and **3**, the proximal end **501** of the tibial nail **500** contains openings **515-518**, including a pair of proximal oblique openings **515**, an AP oblique opening **516**, a proximal ML slot **517** and a proximal ML opening **518**. Each of the proximal oblique openings **515** is configured to receive and guide reconstruction screws and is at an angle relative to the axis of the nail **500**. The angle of each opening **515** relative to the axis is in the range of 45°-60°, and in the illustrated embodiment, are each 55°. The AP oblique opening **516** contains a two-start thread **519** used to create a fixed angle construct with a locking screw. The ML locking slot **517** facilitates relative movement between the nail **500** and the locking screw in the event compression or the like is applied during installation and also provides for static/dynamic locking modes. In the illustrated embodiment, the slot **517** is 7 mm long and starts 36 mm from the proximal end of the nail **500**. The proximal oblique openings **515** are located at 14 and 20 mm from the proximal end and the ML opening is located 57 mm from the proximal end. The opening locations are not limited to the described distances and may be positioned at different locations depending on the anatomy of the bone.

[0026] In the illustrated embodiment, the proximal end **501** of the tibial nail **500** also includes a pair of connection slots **520**. The connection slots **520** are configured to engage projections **549** on the insertion tool **540** to releasably connect the nail **500** to the tool **540**, as will be described in more detail hereinafter. While connection slots **520** are illustrated, other coupling mechanisms, for example, internal threads within the proximal end **501** of the nail **500**, may be employed.

[0027] Having described various features of an illustrative tibia nail **500**, tools, systems and methods of inserting the tibia nail **500** will be described with reference to FIGS. **5-30**. The tibial nail **500** is inserted into the medullary canal through an incision at the entry site. FIG. **5** illustrates an illustrative embodiment of a system **530** for implanting an intramedullary nail **500** utilizing the infra-patellar approach. The infra-patellar approach is one standard approach for insertion of the tibial nail **500**. This approach is typically performed with the leg in the hyper-flexed (HF) position. The tibial nail **500** is inserted directly through the incision into the tibial canal.

[0028] The system **530** includes an insertion tool **540** and an aiming guide **560**. Referring to FIGS. **5-7**, the insertion tool **540** includes a coupling portion **545** and a handle portion **547**. In some embodiments, the coupling portion **545** and the handle portion **547** can be separate parts that are removably joined together, while in other embodiments the coupling portion **545** and the handle portion **547** can be different regions of a single, integrally formed component. The handle portion **547** is preferably rigid, for example, made from stainless steel and carbon fiber and also has provisions to attach an impaction shaft **546** and compression bolt **544**. The coupling portion **545** has a connection portion **548** configured to releasably engage or couple to the proximal portion **501** of the nail **500**. In the illustrated embodiment, the connection portion **548** includes a pair of

projections **549** configured to engage the connection slots **520** on the proximal end **501** of the nail **500**, for example with a friction fit. However, those skilled in the art will understand that other coupling mechanisms, for example, a threaded coupling, may be employed.

[0029] The handle portion **547** includes a connection assembly **550** for releasably attaching the handle portion **547** to the aiming guide **560**. The connection assembly **550** includes a recessed area **552** with a support surface **554** extending between a distal stop surface **551** and a proximal stop surface **553**. A pair of non-threaded bores **555** and a threaded bore **556** extend into the support surface **554**. The non-threaded bores **555** are configured to receive connection posts **572** of the aiming guide **560** while the threaded bore **556** is configured to receive a screw **574** of the aiming guide **560**, as will be described in more detail hereinafter. Those skilled in the art will understand that other connection mechanisms may be employed.

[0030] The tibial nail aiming guide **560** is used to install locking screws into the tibial nail **500**. The aiming guide **560** sets the trajectory of the locking screws to interface with the proximal openings **515-518** of the nail **500**. In at least one embodiment, the aiming guide **560** is made from a radiolucent material. The aiming guide **560** includes an arcuate body **562** which extends between opposed end supports **564**. Each end support **564** defines a hole opening **563**, which aligns with the ML opening **518**, and a slot opening **565**, which aligns with the ML slot **517**. A plurality of intermediate hole openings **567, 568, 569** are defined along the arcuate body **562**, aligned with various openings of the nail **500**. More specifically, the hole opening **567** is aligned with the AP oblique opening **516**, while the hole openings **568, 569** are each aligned with a respective oblique opening **515**.

[0031] The openings **563, 565, 567, 568** and **569** are configured to support respective guide sheaths **579**. The sheaths **579** are used to protect the soft tissue during the drilling process. The sheaths **579** accept drill sleeves and trocars of various sizes. In the present embodiment, the guide sheaths **579** do not include retention members, but instead, a friction retention assembly **580** is provided in each opening **563, 565, 567, 568, 569**. An illustrative friction retention assembly **580** will be described with reference to FIGS. **9-11**.

[0032] Each friction retention assembly **580** includes a friction pad **582, 582'** positioned within a blind bore **581** adjacent to and opening into a respective opening **563, 565, 567, 568, 569**. Each friction pad **582, 582'** extends from a contact surface **583, 583'** to a rear surface **584**. The contact surface **583** for the friction pads **582** associated with the openings **563, 567, 568, 569** has an arcuate configuration which complements the outside surface configuration of the sheath **579**. The contact surface **583'** for the friction pads **582'** associated with the openings **565** has two arcuate portions with each complementing the outside surface configuration of the sheath **579** to accommodate the different positions with which the sheath **579** may be aligned with the ML slot **517**. Additionally, each contact surface **583, 583'** is angled such that it is substantially parallel to the central axis of the respective opening **563, 565, 567, 568, 569** (see FIG. **9**).

[0033] A spring **586** or other biasing member is positioned between the rear surface **584** of the friction pad **582, 582'** and the blind end of the bore **581** to bias the friction pad **582, 582'** toward the respective opening **563, 565, 567, 568, 569** such that the contact surface **583, 583'** extends into the opening **563, 565, 567, 568, 569** such that it may contact and retain the sheath **579**. The rear surface **584** of the friction pad **582, 582'** may include a notch **585** or the like to retain alignment of the spring **586**. To retain the friction pad **582, 582'**, and thereby the spring **586**, within the bore **581**, a retaining pin **589** extends through the body **562** and through a slot **587** defined through the friction pad **582, 582'**. The slot **587** has a length larger than the diameter of the retaining pin **589** such that the friction pad **582, 582'** is axially moveable within the bore **581**, with the slot **587** defining the range of motion of the friction pad **582, 582'**. The friction pads **582, 582'** are generally biased toward the contacting position, however, application of a sufficient force on the sheath **579** will cause the friction pad **582, 582'** to move against the force of the spring **586** into the bore **581** whereby the sheath **579** may be advanced or withdrawn.

[0034] The aiming guide **560** also includes a connection assembly **570** configured to mate with the connection assembly **550** on the insertion handle **540**. The connection assembly **570** includes a body **572** configured to be received within the recessed area **552** of the handle connection assembly **550** with a distal surface **571** contacting the distal stop **551** and a proximal surface **573** contacting the proximal stop surface **553**. A pair of connection posts **574** extend from the body **572** and are configured to be received in the non-threaded bores **555** of the connection assembly **550**. A rotatable screw **576** with a head **578** extends through the body **572** and is configured to threadably engage the threaded bore **556** to secure the aiming guide **560** with the insertion handle **540**. The connector assembly body **575** is a rigid structure and may be made from, for example, metal.

[0035] Accordingly, the system **530** provides an insertion handle **547** with reliable and convenient connection assembly for attaching the aiming guide **560**. A threaded connection with an accessible head allows tool free connection and disconnection of the aiming guide **560**. The insertion handle **547** also contain an external compression bolt **544** used to apply pressure the locking screw in the dynamic position to compress a fracture gap. The aiming guide **560** utilizes friction retention assemblies **580** that lock the soft tissue sheaths **579** in place. The friction retention assembly **580** allows insertion of the soft tissue sheath **579** but prevents it from backing out. This feature helps to maintain the position of the soft tissue sheaths **579** for accurate screw length measurements and facilitates drilling and screw insertion. The aiming guide **560** is designed with extended sheath guides **579** for improved aiming accuracy.

[0036] The supra-patellar approach uses a tibia entry point above the knee. A system **530'** for use with the supra-patellar approach will be described with reference to FIGS. **12-30**. The system **530'** is substantially as in the previous embodiment but further includes a cannula assembly **590**. As illustrated in FIG. **12**, at the time of insertion of the nail **500**, the nail **500** and the connection portion **545** of the insertion tool **540** are inserted through the cannula assembly **590**. The cannula assembly **590** protects the articular surface of the knee during the nail insertion process. As will be described below, the cannula assembly **590** also protects the articular surface of the knee during reaming. The reaming is performed through a drill guide **610** in the cannula **592** of the cannula assembly **590**. Thereafter, the drill guide **610** is removed and nail **500** insertion is performed through the cannula **592** into the entry incision.

[0037] Referring to FIG. **13**, an illustrative cannula assembly **590** will be described. The cannula assembly **590** includes a flexible cannula **592** and a rigid handle **596**. The cannula **592** has a through passage **594** which is aligned with an opening **599** in the handle **596** to define a continuous passage. The soft, flexible cannula **592** is anatomically shaped to fit between the femoral condyles and minimize damage to the articular surface. In one embodiment, the flexible cannula **592** material is over-molded onto the rigid plastic handle **596**. A pair of tibia guide slots **595** extend through the handle **596** and along the sides of the cannula **592**. Transverse femur guide holes **597** extend through the handle **596**. As shown in FIG. **14**, the guide slots **595** and guide holes **597** guide fixation pins **600**, **602** into the tibia **144** or femur **143**.

[0038] The cannula assembly **590** is inserted through an incision in the skin and is the working portal through which the surgeon can perform reaming, drilling, and nail insertion. The guide slots **595** and holes **597** allow the surgeon to fix the cannula **592** in place during the procedure. The guide slots **595** and holes **597** allow the cannula to be fixed to the femur **143** or tibia **144** with converging pins **602**, **600** depending on surgeon preference. The cannula **592** is reversible and can be used on either side of the patient.

[0039] Referring to FIGS. **15-16**, the cannula assembly **590** is designed to accept a drill sleeve **610** and round trocar **650**. In the illustrated embodiment, the cannula **592** is tapered for easy removal of the drill sleeve **610**. The drill sleeve **610** has a sleeve portion **612** configured to slide within the cannula **592** and a housing portion **616** configured to be at least partially received within the opening **599** of the handle **596**. In the illustrated embodiment, a pair of release triggers **624** are flexibly supported relative to the housing portion **616** and define projections **629** which engage



within the handle **596** to lock the drill sleeve **610** relative to the cannula assembly **590**. The release triggers **624** may be flexed toward one another to disengage the projections **629** and remove the drill sleeve **610**. As will be described in greater detail hereinafter, each release trigger **624** defines an axial pin slot area **627** which aligns with a respective guide slot **595** of the cannula assembly **590** to facilitate passage of a respective pin **602** through the drill sleeve **610** and cannula assembly **590**. The trocar **650** extends from a proximal end **651** to a distal end **652** which is configured to extend from the distal end **613** of the drill sleeve **610**. In the illustrated embodiment, a proximal portion of the trocar **650** includes external threads **654** configured to threadably engage internal threads **615** of the drill sleeve **610** (see FIG. 18).

[0040] Turning to FIGS. 17-22, the drill sleeve **610** will be described in more detail. The drill sleeve **610** includes the sleeve portion **612** extending from a proximal end **611** to a distal end **613** with a passage **614** extending therethrough. The housing portion **616** is secured about the proximal end **611** of the sleeve portion **612**. The housing portion **616** of the present embodiment includes two housing halves **618**, **620** which each extend less than 180° such that an axial gap **622** is defined between the halves **618**, **620** on each side of the housing portion **616**. Each of the housing halves **618**, **620** defines a respective radial flange **619**, **621** which together define a stop which contacts the cannula handle **596**.

[0041] A release trigger **624** is positioned within each axial gap **622**. Each trigger **624** is defined by a pair of spaced apart arms **626**, **628** which are each hingedly connected at one end to the housing portion **616** and at the other end are interconnected to one another by a trigger handle **630**. A projection **629** extends outward from each of the arms **626**, **628**. The space **627a** between the arms **626**, **628** defines a first portion of the axial pin slot area **627** while a notch **627b** on the radial inner surface of the trigger handle **630** defines the remainder of the axial pin slot area **627**. The axial pin slot areas **627** allow passage of the pins **602** externally past the housing portion **616** and the sleeve portion **612** as shown in FIGS. 21 and 22. The illustrated trigger handles **630** have a curved configuration with ridges to facilitate gripping of the release triggers **624**, however, it is understood that they may have different configurations.

[0042] Referring to FIGS. 23-30, an alternative drill sleeve **610'** will be described. Again, the cannula assembly **590** is designed to accept the drill sleeve **610'** and round trocar **650**. The drill sleeve **610'** has a sleeve portion **612** configured to slide within the cannula **592** and a housing portion **616'** configured to be at least partially received within the opening **599** of the handle **596**. In the illustrated embodiment, a pair of release triggers **624'** are flexibly supported relative to the housing portion **616'** and define projections **629** which engage within the handle **596** to lock the drill sleeve **610'** relative to the cannula assembly **590**. The release triggers **624'** may be flexed toward one another to disengage the projections **629** and remove the drill sleeve **610'**. As will be described in greater detail hereinafter, each release trigger **624'** defines an axial shelf **631** which aligns with a respective guide slot **595** of the cannula assembly **590** to facilitate passage of a respective pin **602** past the drill sleeve **610** and through the cannula assembly **590**.

[0043] Turning to FIGS. 25-30, the drill sleeve **610'** will be described in more detail. The drill sleeve **610'** includes the sleeve portion **612'** extending from a proximal end **611** to a distal end **613** with a passage **614** extending therethrough. The housing portion **616'** is secured about the proximal end **611** of the sleeve portion **612**. The housing portion **616'** of the present embodiment includes two housing halves **618'**, **620'**. Each of the housing halves **618'**, **620'** defines a respective radial flange **619'**, **621'** which together define a stop which contacts the cannula handle **596**. In the present embodiment, the housing half **620'** extends between side wall surfaces **625** which will define a first surface portion of a guide area **632** for guiding the posts **602**. The release triggers **624'** extend from the other housing half **618'**, above a central plane of the drill sleeve **610'**, and define contact surfaces **631** which define a second surface portion of the guide area **632**.

[0044] Each trigger **624'** of the present embodiment is defined by a single arm **626'** which is hingedly connected at one end to the housing half **618'** and at the other end is connected to the

trigger handle **630'**. A projection **629** extends outward from each of the arms **626**. As described above, each of the release triggers **624'** extends above a central plane of the drill sleeve **610'** such that a lower surface **631** of the arm **626'** is also above the central plane of the drill sleeve **610'**. The lower surface **631** is generally perpendicular to a respective side wall surface **625** such that the surfaces **625**, **631** define a guide area **632** aligned with a respective guide slot **595** of the cannula assembly **590**. The guide areas **632** allow passage of the pins **602** externally past the housing portion **616'** and the sleeve portion **612** as shown in FIGS. **29** and **30**. The illustrated trigger handles **630'** have a curved configuration with ridges to facilitate gripping of the release triggers **624'**, however, it is understood that they may have different configurations.

[0045] The above detailed descriptions of embodiments of the technology are not intended to be exhaustive or to limit the technology to the precise form disclosed above. Although specific embodiments of, and examples for, the technology are described above for illustrative purposes, various equivalent modifications are possible within the scope of the technology, as those skilled in the relevant art will recognize. For example, while steps are presented in a given order, alternative embodiments may perform steps in a different order. The various embodiments described herein may also be combined to provide further embodiments.

[0046] From the foregoing, it will be appreciated that specific embodiments of the invention have been described herein for purposes of illustration, but well-known structures and functions have not been shown or described in detail to avoid unnecessarily obscuring the description of the embodiments of the technology. Where the context permits, singular or plural terms may also include the plural or singular term, respectively.

[0047] Moreover, unless the word “or” is expressly limited to mean only a single item exclusive from the other items in reference to a list of two or more items, then the use of “or” in such a list is to be interpreted as including (a) any single item in the list, (b) all of the items in the list, or (c) any combination of the items in the list. Additionally, the term “comprising” is used throughout to mean including at least the recited feature(s) such that any greater number of the same feature and/or additional types of other features are not precluded. It will also be appreciated that specific embodiments have been described herein for purposes of illustration, but that various modifications may be made without deviating from the technology. Further, while advantages associated with certain embodiments of the technology have been described in the context of those embodiments, other embodiments may also exhibit such advantages, and not all embodiments need necessarily exhibit such advantages to fall within the scope of the technology. Accordingly, the disclosure and associated technology can encompass other embodiments not expressly shown or described herein.

## Claims

1. A tibial nail system configured to stabilize a tibia of a patient, the system comprising: a tibial nail configured to be inserted into an intramedullary canal of the tibia in a supra-patellar approach and having: a proximal portion having a plurality of proximal locking holes which include at least one proximal AP hole arranged in an anterior-posterior direction and at least one proximal ML hole arranged in a medial-lateral direction, wherein the at least one proximal AP hole includes a two-start thread for creating a fixed angle construct with a locking screw; a distal portion having a plurality of distal locking holes which include at least one distal AP hole arranged in an anterior-posterior direction and at least one distal ML hole arranged in a medial-lateral direction, wherein the at least one distal AP hole includes a two-start thread for creating a fixed angle construct with a locking screw; an elongate body extending between the proximal portion and the distal portion along a longitudinal axis, wherein the proximal and distal portions respectively form proximal and distal angles relative to the elongate body longitudinal axis, the distal angle being smaller than the proximal angle; an insertion assembly configured to be coupled to the tibial nail.

2. The system of claim 1, wherein twice the distal angle is smaller than the proximal angle.

3. The system of claim 1, wherein the at least one distal ML hole includes a two-start thread for creating a fixed angle construct with a locking screw.
4. The system of claim 1, wherein the plurality of proximal locking holes includes a proximal ML slot adapted to compress a fracture in the tibia.
5. The system of claim 4, wherein the proximal ML slot is positioned along the proximal angle.
6. The system of claim 1, wherein: the plurality of proximal locking holes includes a proximal ML slot adapted to compress a fracture in the tibia and positioned along a line defined by the proximal angle; and the at least one proximal ML hole is also positioned on the line defined by the proximal angle.
7. The system of claim 6, wherein the plurality of proximal locking holes include a pair of oblique openings for receiving bone screws and positioned proximally of the at least one proximal AP hole.
8. The system of claim 1, wherein: the at least one distal AP hole includes two and only two holes; and the at least one distal ML hole includes two and only two holes for a total of four bone screw holes in the distal portion.
9. The system of claim 8, wherein the two distal ML holes are positioned on a line defined by the distal angle.
10. The system of claim 1, wherein: the proximal portion includes first and second slots; and the insertion assembly includes first and second projections configured to respectively engage the first and second slots.
11. A tibial nail system configured to stabilize a tibia of a patient, the system comprising: a tibial nail configured to be inserted into an intramedullary canal of the tibia and having: a proximal portion having a proximal end and a plurality of proximal locking holes which include at least one proximal oblique AP hole arranged in an anterior-posterior direction and at least one proximal ML hole arranged in a medial-lateral direction, wherein the at least one proximal oblique AP hole includes a two-start thread for creating a fixed angle construct with a locking screw; a distal portion having a plurality of distal locking holes which include at least one distal AP hole arranged in an anterior-posterior direction and at least one distal ML hole arranged in a medial-lateral direction, wherein the at least one distal AP hole includes a two-start thread for creating a fixed angle construct with a locking screw; an elongate body extending between the proximal portion and the distal portion along a longitudinal axis, wherein the proximal and distal portions respectively form proximal and distal angles relative to the elongate body longitudinal axis, the distal angle being smaller than the proximal angle; an insertion assembly configured to be coupled to the proximal end of the tibial nail and including: an insertion coupler configured to be attached to the tibial nail; a handle extending from the insertion coupler; and an aiming guide configured to be attached to the insertion coupler.
12. The system of claim 11, wherein twice the distal angle is smaller than the proximal angle.
13. The system of claim 11, wherein the at least one distal ML hole includes a two-start thread for creating a fixed angle construct with a locking screw.
14. The system of claim 11, wherein the plurality of proximal locking holes includes a proximal ML slot adapted to compress a fracture in the tibia.
15. The system of claim 14, wherein the proximal ML slot is positioned along the proximal angle.
16. The system of claim 11, wherein: the plurality of proximal locking holes includes a proximal ML slot adapted to compress a fracture in the tibia and positioned along a line defined by the proximal angle; and the at least one proximal ML hole is also positioned on the line defined by the proximal angle.
17. The system of claim 16, wherein the plurality of proximal locking holes include a pair of oblique openings for receiving bone screws and positioned proximally of the at least one proximal oblique AP hole, each oblique opening being at an angle of 55 degrees relative to an axis of the proximal portion.
18. The system of claim 11, wherein: the at least one distal AP hole includes two and only two

holes; and the at least one distal ML hole includes two and only two holes for a total of four bone screw holes in the distal portion.

**19.** The system of claim 18, wherein the two distal ML holes are positioned on a line defined by the distal angle.

**20.** The system of claim 11, wherein: the proximal portion includes first and second slots; and the insertion assembly includes first and second projections configured to respectively engage the first and second slots.

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