June 21, 1966 E. J. HABOUSH 3,256,877

ADJUSTABLE NAIL PLATE JOINT

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FIG.1.

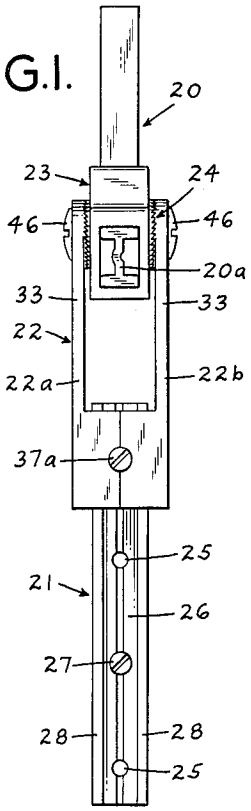


FIG.2.

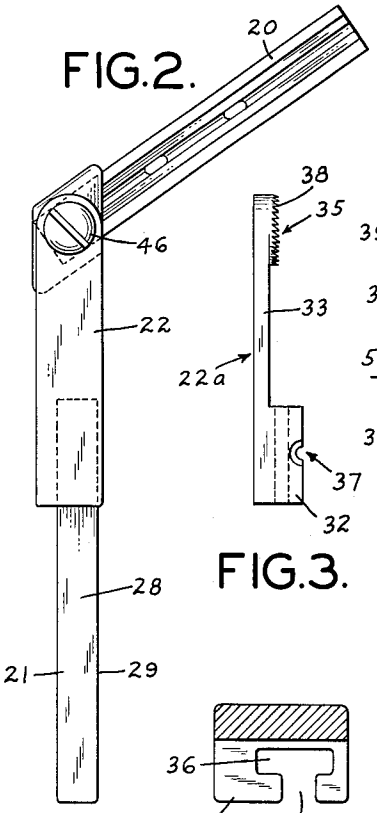


FIG.4.

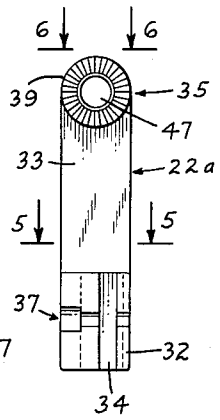


FIG.3.

FIG.6.

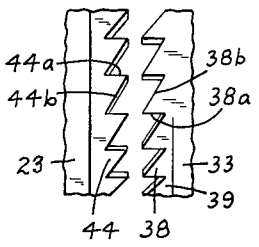
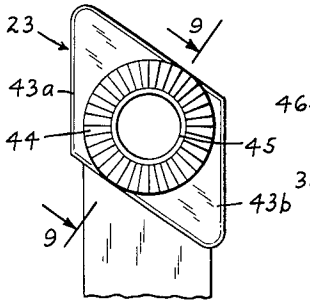


FIG.5.

FIG.7.



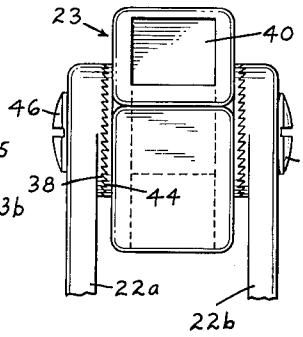
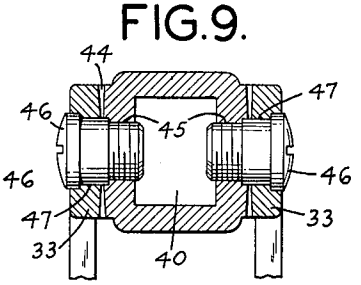


FIG.8.

FIG.9.



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FIG.10.

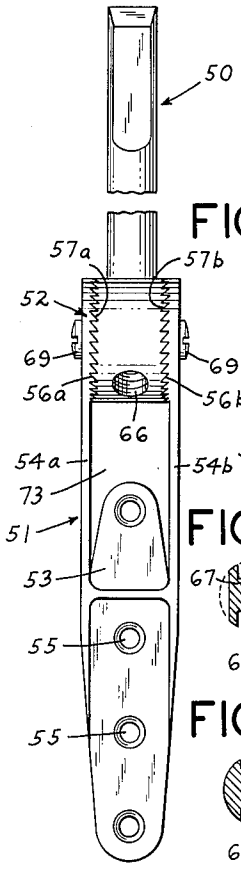


FIG.11.

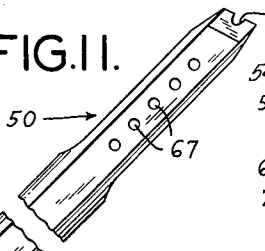


FIG.17.

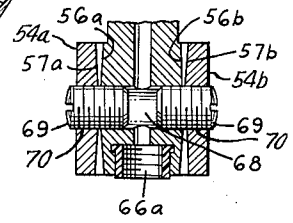




FIG.22.

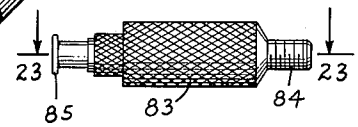
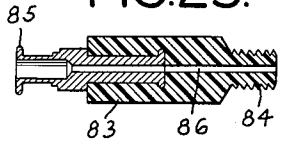


FIG.23.



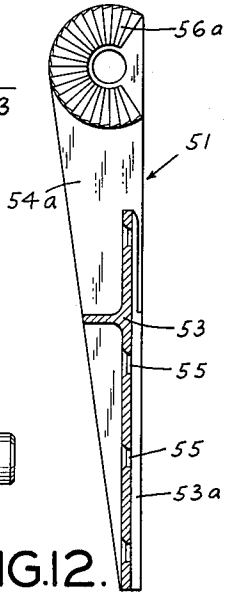


FIG.16.

FIG.15.

FIG.18.

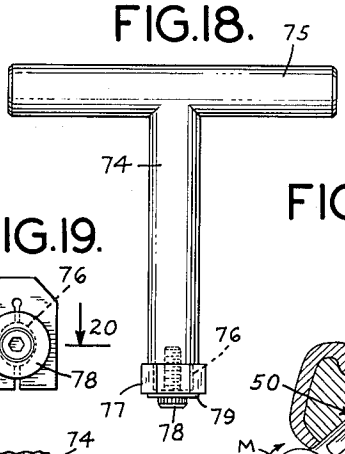


FIG.12.

FIG.19.

FIG.13.

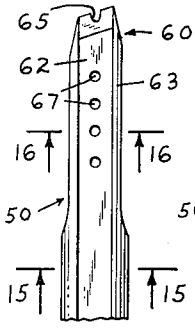
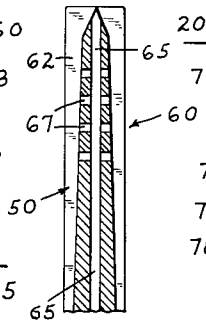


FIG.14.



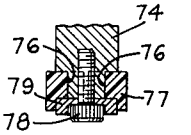
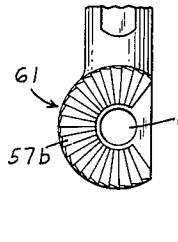
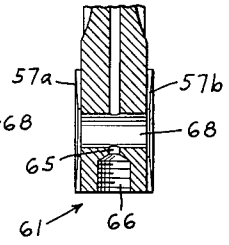


FIG.20.





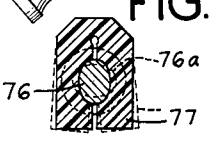


FIG.21.

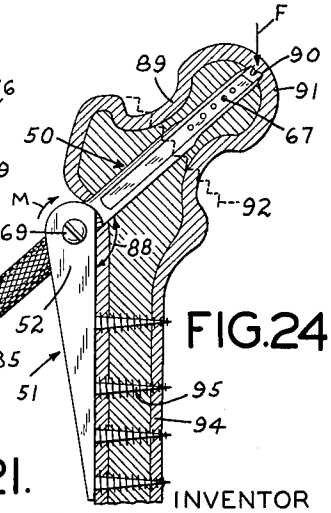


FIG.24.

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United States Patent Office 3,256,877 Patented June 21, 1966

3,256,877

ADJUSTABLE NAIL PLATE JOINT

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Filed Dec. 11, 1961, Ser. No. 158,385
6 Claims. (Cl. 128—92)

This invention relates, generally, to a new and improved nail plate for the surgical treatment of bone fractures and, in particular, to an adjustable nail and nail plate assembly for the treatment of fractures of the femur.

The treatment of fractures of the hip by internal fixation is now well known. Pins, multiple wires, and nails in various sizes were first introduced for this purpose. Soon thereafter a nail was developed that could be cut in length to eliminate the need for various sizes. Subsequently the need for nail plates for the treatment of intertrochanteric fractures, became evident and they were introduced.

In the course of time, the number of devices for the surgical treatment of bone fractures has proliferated, so that today our armamentarium includes innumerable nails and nail plates of various sizes, shapes, and angles. This has created the problem of maintaining many diverse devices and special instruments for surgical treatment of bone fractures. Any innovation that simplifies the complexity of nails and nail plates would not only reduce the steps in an operation but also diminish the length of anesthesia, morbidity and mortality.

According to this invention, a two piece nail and nail plate assembly is provided in which the nail is hingedly connected to the nail plate. A ratchet joint in the hinge transmits bending forces from the nail to the nail plate. The ratchet joint may be made self-locking if desired.

For a better understanding of the invention, reference is made to the following detailed description thereof and to the accompanying drawings in which:

FIGURES 1 and 2 show a preferred embodiment of this invention in which a Haboush universal nail is used for both the nail and nail plate;

FIGURES 3 through 9 show the detailed construction of the various parts of the preferred embodiment shown in FIGURES 1 and 2;

FIGURES 10 and 11 show another preferred embodiment providing a special one-piece nail and one-piece plate;

FIGURES 12 through 17 show the detailed construction of the various parts of the embodiment shown in FIGURES 10 and 11;

FIGURES 18 to 21 illustrate the spreading tool for resetting the nail position;

FIGURES 22 and 23 illustrate an adapter to permit injection of a bone building solution; and

FIGURE 24 shows a typical nail and nail plate insertion.

Referring to FIGURES 1 and 2, the reference numerals **20** and **21** designate, respectively, a nail, (adapted to be inserted through the femur and upwardly into the neck of the femur) and a plate (adapted to be attached by screws to the femoral shaft). The nail and the plate are connected to each other by means of a plate holder **22**, a nail stem **23**, and a ratchet joint **24** therebetween.

The nail **20** is of H beam construction, whose cross section may be seen in FIGURE 1 at **20***a*. The plate **21** is likewise of H beam construction. Screw holes **25** are provided in the web **26** of the plate for receiving screws **27** (of which one is shown) to attach the plate to the femoral shaft. The flanges **28** of plate **21** are oriented approximately vertically to the surface of the femoral shaft and rest thereon by edges **29**. Web **26** of the plate is therefore approximately parallel to the femoral shaft.

An important part of this invention resides in the assembly for joining the nail and plate, such assembly comprising a plate holder **22**, nail stem **23**, and ratchet joint **24**. The plate holder **22**, is formed of two members **22***a* and **22***b* (FIG. 1) of which **22***a* is illustrated in detail in FIGURES 3, 4, 5 and 6. Member **22***b* is a mirror image of member **22***a*. As shown by FIGURES 3 and 4, member **22***a* is comprised of an arm **33** extending from a base **32**, a plate slot **34** formed in the base, and a ratchet face **35** embossed on the inner side of the upper end of arm **33**.

A detailed view of plate slot **34** is shown in FIGURE 5. The slot has a T-shaped cross section **36** and is adapted thereby to slidably engage half of the H beam section of plate **21**. The mating plate holder, **22***b* is similarly slotted to engage the other half of the H beam plate **21**. Half of a screw hole **37** (FIGS. 3 and 4) is provided in each half of the plate holder **22***a* and **22***b*. Insertion of a screw **37***a* (FIG. 1) in hole **37** serves simultaneously to hold the two halves **22***a* and **22***b* of the plate holder firmly to the plate **21**.

As stated, the upper end of the arm **33** carries a ratchet face **35** comprised of radial ratchet teeth **38** formed on a circular boss **39** and projecting inwardly from arm **33**. A detailed section of the radial ratchet teeth is shown in FIGURE 6 wherein a typical tooth **38** is shown.

The ratchet teeth **38** on arm **22***a* (FIG. 8) engage the mating ratchet teeth **44** on one side of the nail stem **23** to form half of the ratchet joint **24**. The other half of the ratchet joint is formed by similar ratchet teeth in the plate holder member **22***b* which engages ratchet teeth formed on the other side of nail stem **23**. A bending moment developed by the body weight acting on the lever arm of the nail **20** is accordingly transmitted from the nail **20** to the plate **21** by means of ratchet point **24**.

As shown in detail in FIGS. 7, 8 and 9, the nail stem **23** comprises a member having formed therein a box-like channel **40** with open ends adapted to slidably engage nail **20**. FIGURE 9 shows a section through this channel looking along the axis thereof. The ends **43***a* and **43***b* (FIG. 7) of the nail stem are cut at an acute angle to the axis of the channel so that they will be approximately parallel to the vertical sides of the plate holder **22** when the entire assembly is inserted in the bone. Locking means are provided rigidly engaging nail stem **23** to nail **20**. A simple friction fit is sufficient, as shown in FIGS. 1 and 2. Alternatively pins or a set-screw may be provided.

As stated, the sides of the stem **23** have ratchet teeth **44** thereon which mate with the cooperating ratchet teeth **38** of the ratchet face **35** of the plate holder. The nail stem has formed therein on opposite sides a pair of internally threaded holes **45** which receive screws **46**. The screws slidably fit through unthreaded holes **47** (FIGS. 4 and 9) centrally formed in the bosses of plate holder members **22***a* and **22***b*. If desired, the screws **46** may be replaced by pins extending from the nail stem into holes **47** and having a friction fit in holes **45** and **47**. Arms **22***a* and **22***b* springedly engage nail stem **23**. Ratchet joint **24** may thereby be adjusted stepwise when screws **46** are not fully advanced into their respective holes **45**. After adjusting the nail and plate to the desired angular position, screws **46** are tightened to lock the ratchet joint **24** firmly.

When the nail and nail plate assembly is used for treatment of intertrochanteric fractures of the femur, there are substantial bending forces on the ratchet joint tending to rotate the nail clockwise relative to the nail plate. It is preferable, therefore, that ratchet joint **24** be designed to prevent clockwise rotation of the nail in the event that screws **46** are accidentally loosened.

This is accomplished by using ratchet teeth having a set of faces **38***a* (FIGURE 6) substantially co-planar with the axis of rotation and a set of faces **38***b* at an acute angle thereto. Teeth **44** on nail stem **23** have con-

forming faces **44***a* and **44***b*. Faces **38***a* of ratchet teeth **38** face counterclockwise and the corresponding faces **44***a* of ratchet teeth **44** face clockwise.

When the ratchet teeth **38** and **44** are springedly engaged by arms **22***a* and **22***b*, faces **38***a* and the corresponding faces **44***a* will engage to prevent clockwise rotation of nail **20**. Counterclockwise rotations of nail **20**, however will engage the sloping faces **38***b* of teeth **38** and the corresponding faces **44***b* of teeth **44**. Arms **22***a* and **22***b* will thereby be forced aside permitting rotational adjustment of the nail in the counterclockwise direction.

Another embodiment of the invention is illustrated in FIGURES 10–17. Referring first to FIGURES 10 and 11, shown therein is a nail **50** and a nail plate **51** joined by a ratchet joint **52**.

In this embodiment, the nail plate and the nail plate holder are combined in a single integral piece **51** comprised of (FIGS. 10 and 12) a web **53** and integral side arms **54***a* and **54***b* extending upwardly from web **53**. Arms **54***a* and **54***b* springedly engage ratchet joint **52**. The side members **54***a* and **54***b* rest substantially vertically on the femoral shaft and the web **53** is substantially parallel to the femoral shaft. Screw holes **55** are provided in the web whereby the nail plate **51** can be screwed to the femoral shaft. The upper ends of the arms **54***a*, **54***b*, carry respective sets of ratchet teeth **56***a*, **56***b* which mate with cooperating sets of ratchet teeth **57***a*, **57***b* in the nail **50** to form a ratchet joint **52** similar to the already described ratchet joint **24**. Preferably spring arms **54***a* and **54***b* extend free of web **53** from the mid-portion of the web. This permits greater flexibility in arms **54***a* and **54***b* without requiring unduly thin cross sections. Web **53** may have a concave lower surface **53***a* (FIG. 12) so that it will conform more closely to the femoral shaft.

Nail **50** is shown in detail in FIGURES 13, 14, 15 and 16. The nail comprises a modified H beam section **60** which is integrally attached to a base **61** of generally cylindrical cross section (FIG. 14).

The web **62** of H beam section **60** is of variable thickness as illustrated in the sections shown in FIGURES 15 and 16. Likewise the flanges **63** of the H beam are of variable shape. On the lower portion of the nail the flange has cylindrically shaped outer surface (FIG. 15) while on the upper portion of the nail the flanges are flat. At both ends of the cylindrical base **61** are ratchet teeth **57***a* and **57***b* which mate with cooperating ratchet teeth **56***a* and **56***b* of the nail plate **51**. A hole **65** is drilled lengthwise through the web of the H beam, in order to accommodate a guide wire. The cylindrical base **61** is provided with a threaded hole **66** to accommodate a conventional nail driving and extracting tool.

It is known that the rate at which bone fractures heal is promoted by bone building substances such as collagen chondroitin sulfate. Accordingly transverse holes **67** are provided through the web of the nail in communication with the guide wire hole **65**. Thus after insertion of the nail, the guide wire may be removed and a solution containing collagen chondroitin sulfate injected through holes **65** and **67** (described more fully below).

Referring to FIGURE 17, the ratchet section of the nail plate holder is shown at **56***b*, and the ratchet section of the nail is shown at **57***b*. Passing horizontally through base **61** is a central internally threaded hole **68** receiving screws **69**. Screws **69** engage in threaded hole **68** and provide an axis around which ratchet joint **52** may pivot. Ratchet teeth **56***a*, **56***b*, **57***a* and **57***b* are automatically locking when the nail is rotated in a clockwise direction as described above.

The arms **54***a* and **54***b* carrying the ratchet teeth **57***a* and **57***b* pivot around screws **69** which fit through holes **70**. Holes **70** are not threaded so that they do not engage the threads of screws **69**. The arms **54***a* and **54***b*, therefore, will always be free to spring outwardly and permit adjustment of the nail and nail plate.

Because of the self locking feature the nail is adjustable in only a counterclockwise direction. In some cases, however, it may be necessary to reset the angular position of the nail in the clockwise direction. For this purpose a spreading tool is provided which may be inserted in the space **73** (FIG. 10) between the arms **54***a* and **54***b*. This tool is illustrated in FIGURES 18 through 21. The tool comprises a handle having a shank **74** and a cross-arm **75**. The bottom tip **76** of the shank **74** has an elliptical shape. A resilient, split pad **77** fits over tip **76** and is fastened thereto by a screw **78** and washer **79**. As illustrated in FIG. 21 a 90° turn of the handle will rotate the elliptical tip from **76** (solid) to **76***a* (dotted) and thereby expand the split pad **77**. When inserted in space **73**, and expanded as illustrated, arms **54***a* and **54***b* are spread, whereby ratchet joint **52** is released and the position of the nail may be freely adjusted. To avoid scratches on the nail plate which might lead to corrosion, pad **77** is preferably of a soft, plastic material which may be sterilized such as Teflon.

To inject the collagen chondroitin sulfate solution mentioned above a special adapter and a conventional hypodermic syringe is used. The adapter piece is illustrated in FIGURES 22 and 23. The adapter comprises knurled adapter member **83** having a threaded end **84** adapted to screw into hole **66** in the base of the nail. A fitting **85** is provided on the other end of the cylinder which fits a conventional hypodermic syringe (not shown). A central hole **86** through cylindrical member **83** provides for passage of the injected fluid from the syringe to the guide hole **65** and thence to holes **67**. The solution of collagen chondroitin sulfate injected may also have dissolved therein an X-ray opaque tracing compound such as a radio-opaque iodine salt to permit X-ray observation of the penetration of the collagen chondroitin sulfate.

Because scratches on the nail or nail plate tend to cause corrosion, the adapter member **83** is made of a soft, plastic material, which may be sterilized such as Teflon. Alternatively, however, hole **66** in base **61** may be provided with a Teflon insert **66***a* as illustrated in FIGURE 17, and adapter **83** may be made of corrosion resistant alloy. If a plastic insert is provided as in hole **66***a*, a small shoulder is required to hold the insert in place when an extractor tool is used.

The manner in which the nail and nail plate of FIGS. 10–17 is used to treat a fracture of the femur is illustrated in FIG. 24. The nail **50** and nail plate **51**, are adjusted so that the angle **88** therebetween is less than the final angle to be assumed. Nail **50** is inserted in an intermedullary position upwardly through the neck **89** of the femur until the tip **90** of the nail is imbedded in the head **91** of the femur thereby spanning the fracture zone **92**. When this is done, nail plate **51**, will automatically assume the correct position. The nail plate **51** is screwed to the femoral shaft **94** by screws **95**. If it is necessary to reset angle **88**, the spreader tool described above is inserted into the space **73** (FIG. 10) to release the ratchet joint **52**.

As mentioned above, collagen chondroitin sulfate solution may be injected to accelerate healing of the fracture. As illustrated in FIGURE 24, adapter member **83** is screwed into the base of the nail. A hypodermic syringe **96** is attached to the other end of adapter **83**.

The use of the embodiment shown in FIGS. 1–9 is analogous.

An important feature of the adjustable nail plate is that the strength of the assembled device must be sufficient to support the stresses placed upon it by the human body. Referring to the typical adjustable nail and plate shown in FIG. 24, the body weight is assumed to act at the tip **90** of the nail with a force F. This induces a bending movement M at the ratchet joint **52**. For illustrative purposes the strength of the assembly was calculated assuming that the nail and nail plate was manufactured from Haynes alloy No. 21, a cobalt-based corrosion resistant casting alloy. This material has an ultimate

strength of 101,300 p.s.i., a yield strength of 82,300 p.s.i., and a fatigue strength of 40,000 p.s.i. at 10^8 cycles. The modulus of elasticity for this alloy is 36×10^6 p.s.i. Nail **50** is assumed to be 4.5" long and to have a circular cross section of 0.5" diameter near the base **61**.

The maximum bending stress occurs in the nail near the base (where the nail is of circular cross section). The stresses induced by a force F acting at the tip **90** of the nail is calculated from the formula:

$$S = \frac{FL\frac{h}{2}\cos\alpha}{I}$$

where

L is the length of the nail,
$h/2$ is the radius of the cross section,
I is the moment of inertia of the cross section, and
Cos α is the cosine of angle **88**.

The maximum allowable stress is 101,300 p.s.i. (ultimate tensile strength). In practice however, the maximum stress should be less than the yield point (82,300 p.s.i. in this case) and preferably less than the fatigue strength. Assuming that nail **50** is inserted upwardly through the neck of the femur at an angle of 45°, the maximum force F which may be supported at the tip **90** of the nail is approximately 320 pounds at the yield strength of the material.

It is important that the elastic deflection below the yield point be small so that it will not interfere with the healing of the fracture. The deflection, d, may be calculated from the formula,

$$d = \frac{s l_e^2}{3hE}$$

where

E is the modulus of elasticity, and
l_e is the effective length for deflection

Assuming an s of 82,300 p.s.i. and an l_e of about 4 in., the deflection will be about .05 in. This is acceptably small.

Similar calculations have been made for the ratchet wherein a typical tooth has a mean radius of .275 inch, and the area available for shear at the base of the tooth is .0275 square inches.

The bending moment for a 320 lb. force on a nail inserted at an angle of 45° is 1020 inch-pounds. For Haynes alloy 21, having a shear strength of approximately 41,000 p.s.i., four ratchet teeth in contact will sustain a bending movement M of 1230 inch-pounds. The nail is designed to have at least 12 teeth in contact.

The strength and size requirements for other embodiments of this invention may be similarly calculated according to the well known principles of the strength of materials and biomechanics. In this connection, reference is made to the detailed analysis of the biomechanics of nails and nail plates which appears in the paper "Biomechanics of Femoral Nail and Nail Plate Insertions in Fractures of the Neck of the Femur," Bulletin of the Hospital for Joint Diseases, volume XIV, page 125.

The above described embodiments being exemplary only, it is to be understood that additions thereto, omissions therefrom and modifications thereof can be made without departing from the spirit of the invention, and that the invention comprehends embodiments differing in form and/or detail from these specifically disclosed herein. For example, the ratchet joint may be formed from a single pair of ratchet faces, or may comprise a single arm on the nail plate engaged by a forked member on the nail. Alternate shapes for the nail, nail plate, nail plate holder and nail stem are likewise within the spirit of this invention. Accordingly, the invention is not to be considered as limited save as is consonant with the recitals of the following claims.

I claim:

1. A surgical nail and nail plate assembly comprising a surgical nail plate, a nail plate arm attached to said nail plate having one end extending therefrom, a surgical nail, and an axle extending between the extended end of said arm and one end of said nail hingedly engaging said nail and said arm together, a first annular array of ratchet teeth on the extended end of said arm substantially coaxial with said axle, said ratchet teeth having a first set of faces substantially coplanar with said axle and a second set of faces at an angle to said axle, each of said second faces extending between adjacent faces of said first set, and a second annular array of ratchet teeth on said one end of said nail mating with said first annular array of ratchet teeth, said second annular array being substantially coaxial with said axle and having a first set of faces substantially coplanar with said axle which are adapted to engage said first set of faces of said first annular array and a second set of faces in said second annular array at an angle to said axle which are adapted to slidably engage said second set of faces on said first annular array, means springedly biasing said mating ratchet teeth into interengagement with each other, said ratchet teeth and said biasing means thereby permitting said nail to be slidably and selectively adjusted in one rotational direction relative to said nail plate, and preventing rotation in the opposite rotational direction.

2. A surgical nail and nail plate assembly comprising a surgical nail plate, a pair of transversely spaced nail plates arms attached to said nail plate having transversely resilient ends extending therefrom, a surgical nail having one end interposed between the extended ends of said arms, an axle extending between said extended ends and said one end for hingedly engaging said one end and said arms to each other, first annular arrays of ratchet teeth on the extended ends of said arms coaxial with said axle, said ratchet teeth having a first set of faces substantially coplanar with said axle and a second set of faces at an angle to said axle, each of which extends between adjacent faces of said first set, and second annular arrays of ratchet teeth on said one end which mate with and engage the arrays of ratchet teeth on said arms, said second annular arrays having a first set of faces substantially coplanar with said axle and adapted to engage said first faces of said first annular array and a second set of faces at an angle with said axle adapted to slidably engage said second set of teeth of said first array, said interengaging ratchet teeth thereby permitting said nail to be selectively adjusted relative to said nail plate in one rotational direction and preventing rotation in the opposite rotational direction.

3. A surgical nail and nail plate assembly according to claim **2** which further comprises a pair of screws each of which pass transversely through an unthreaded hole formed in a respective one of the extended ends of said arms and each of which screws is adapted to engage a respective threaded hole formed in said one end of said nail, said screws further having means for locking mating pairs of ratchet teeth on said arm and said one end of said nail into engagement with each other when said screws are threaded into said threaded hole.

4. A nail and a nail plate assembly according to claim **2** wherein a cylindrical hub is integrally attached to said one end of said nail, on which hub are formed said second annular arrays of ratchet teeth.

5. A surgical nail and nail plate assembly according to claim **2** wherein said nail is formed with a bore running axially through the length thereof and transverse holes near the tip of said nail connecting with said axial bore, and means are provided at the base of said nail to receive a syringe, whereby an osteogenic factor may be injected through said annular bore and transverse holes to accelerate the healing of the fracture.

6. A surgical nail and nail plate assembly according to claim **2** further comprising a nail plate holder having a base slidably engaging said nail plate, said base having

locking means to engage said nail plate, and having said nail plate arms integrally formed with said base and extending away therefrom, the extended end of said arms having said first annular array of ratchet teeth formed thereon, and a nail stem slidably receiving said nail and having locking means to engage said nail, said nail stem being hingedly engaged to the extended end of said arm by means of said axle, and having said second annular array of ratchet teeth formed thereon.

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