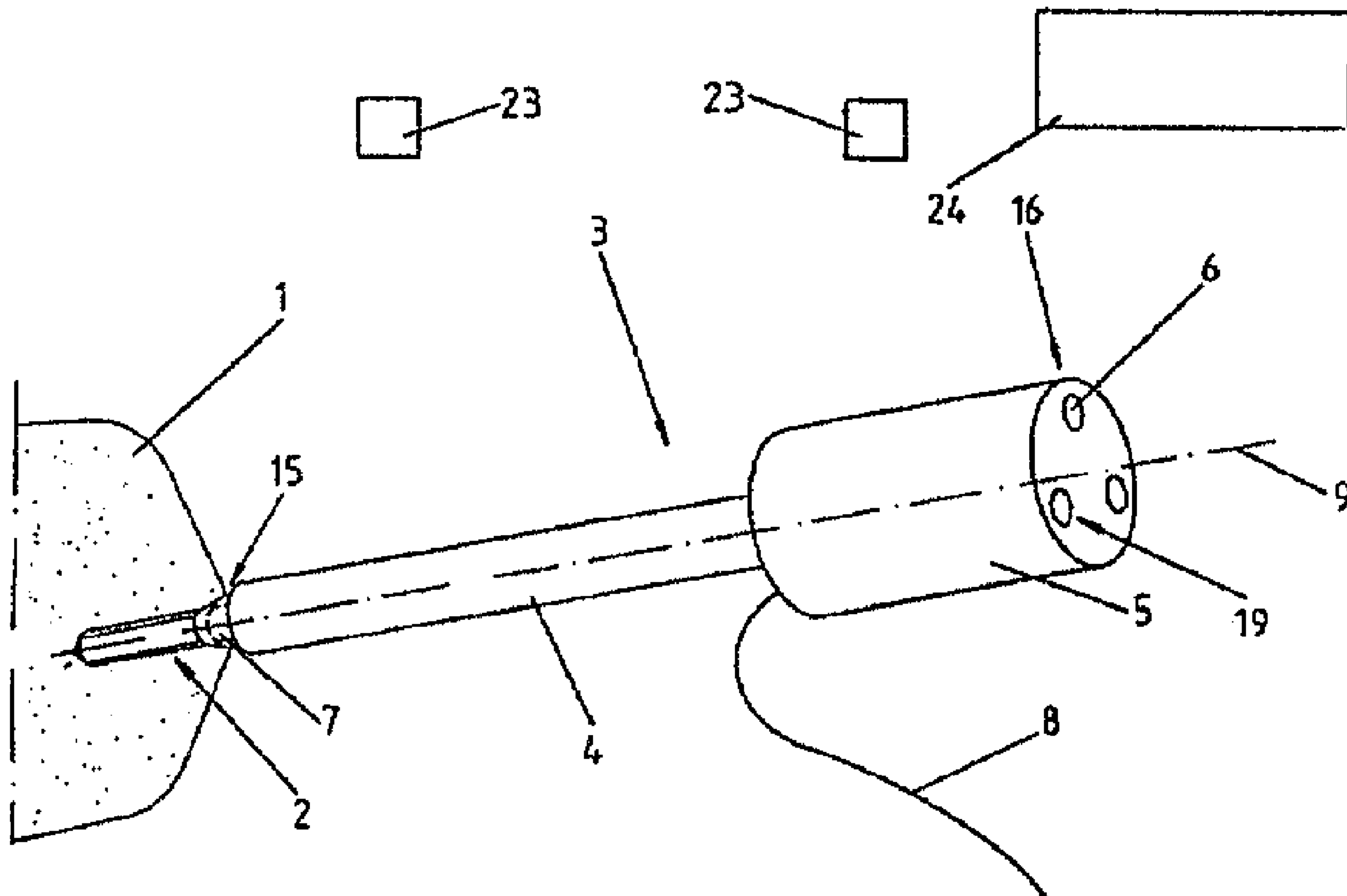




(86) Date de dépôt PCT/PCT Filing Date: 1998/06/22
 (87) Date publication PCT/PCT Publication Date: 1999/12/29
 (45) Date de délivrance/Issue Date: 2008/12/30
 (85) Entrée phase nationale/National Entry: 2000/12/21
 (86) N° demande PCT/PCT Application No.: CH 1998/000269
 (87) N° publication PCT/PCT Publication No.: 1999/066853

(51) Cl.Int./Int.Cl. *A61B 19/00* (2006.01),
A61B 6/12 (2006.01)
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(54) Titre : ALIGNEMENT DE REFERENCE A L'AIDE DE VIS DE REPERE
 (54) Title: FIDUCIAL MATCHING BY MEANS OF FIDUCIAL SCREWS



(57) Abrégé/Abstract:

The invention relates to a device for the referenced positioning of two reference points (11; 14) situated on a fiducial screw (2) implanted into a bone. Said device comprises (A) a fiducial screw (2) which can be screwed into a bone (1) and has a longitudinal

(57) **Abrégé(suite)/Abstract(continued):**

axis (9), a screw shank (10) and a screw head (22) provided with means (12) for receiving an instrument used to screw the fiducial screw (2) in and out; and B) a pointer (3) provided with at least three means (19) which are not positioned colinearly and emit electromagnetic or acoustic waves, where said pointer (3) has a front end (15), a rear end (16) and a longitudinal axis (9). C) The pointer (3) has means (20) at its front end (15) and the fiducial screw (2) at its head (22) which make it possible for the pointer (3) and the fiducial screw (2) to be joined in the direction of the longitudinal axis (9) and concentrically in relation to said axis (9). D) thanks to the known length (x) of the fiducial screw (2), the known length (y) of the pointer (3) and the means (20) described under C) it is possible to achieve a defined, local coordination between the reference points (11; 14) on the fiducial screw (2) and the means (19) of the pointer (3) emitting electromagnetic or acoustic waves.



PCT WELTORGANISATION FÜR GEISTIGES EIGENTUM
Internationales Büro
INTERNATIONALE ANMELDUNG VERÖFFENTLICHT NACH DEM VERTRAG ÜBER DIE
INTERNATIONALE ZUSAMMENARBEIT AUF DEM GEBIET DES PATENTWESENS (PCT)

<p>(51) Internationale Patentklassifikation ⁶ : A61B 19/00</p>	<p>A1</p>	<p>(11) Internationale Veröffentlichungsnummer: WO 99/66853 (43) Internationales Veröffentlichungsdatum: 29. Dezember 1999 (29.12.99)</p>
<p>(21) Internationales Aktenzeichen: PCT/CH98/00269 (22) Internationales Anmeldedatum: 22. Juni 1998 (22.06.98) (71) Anmelder (für alle Bestimmungsstaaten ausser CA US): SYNTHES AG CHUR [CH/CH]; Grabenstrasse 15, CH-7002 Chur (CH). (71) Anmelder (nur für CA): SYNTHES (U.S.A.) [US/US]; 1690 Russell Road, P.O. Box 1766, Paoli, PA 19301-1222 (US). (72) Erfinder; und (75) Erfinder/Anmelder (nur für US): TRAXEL, Doris [CH/CH]; St.-Alban-Vorstadt 43, CH-4052 Basel (CH). BERGER, Roger [CH/CH]; St. Pantaleonstrasse 20, CH-4413 Büren (CH). (74) Anwalt: LUSUARDI, Werther; Dr. Lusuardi AG, Kreuzbühlstrasse 8, CH-8008 Zürich (CH).</p>		<p>(81) Bestimmungsstaaten: AU, CA, JP, MX, US, europäisches Patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE). Veröffentlicht <i>Mit internationalem Recherchenbericht. Mit geänderten Ansprüchen.</i></p>
<p>(54) Title: FIDUCIAL MATCHING BY MEANS OF FIDUCIAL SCREWS</p>		
<p>(54) Bezeichnung: FIDUCIAL MATCHING MITTELS FIDUCIAL-SCHRAUBE</p>		
<p>(57) Abstract</p>		
<p>The invention relates to a device for the referenced positioning of two reference points (11; 14) situated on a fiducial screw (2) implanted into a bone. Said device comprises (A) a fiducial screw (2) which can be screwed into a bone (1) and has a longitudinal axis (9), a screw shank (10) and a screw head (22) provided with means (12) for receiving an instrument used to screw the fiducial screw (2) in and out; and B) a pointer (3) provided with at least three means (19) which are not positioned colinearly and emit electromagnetic or acoustic waves, where said pointer (3) has a front end (15), a rear end (16) and a longitudinal axis (9). C) The pointer (3) has means (20) at its front end (15) and the fiducial screw (2) at its head (22) which make it possible for the pointer (3) and the fiducial screw (2) to be joined in the direction of the longitudinal axis (9) and concentrically in relation to said axis (9). D) thanks to the known length (x) of the fiducial screw (2), the known length (y) of the pointer (3) and the means (20) described under C) it is possible to achieve a defined, local coordination between the reference points (11; 14) on the fiducial screw (2) and the means (19) of the pointer (3) emitting electromagnetic or acoustic waves.</p>		

FIDUCIAL MATCHING BY MEANS OF FIDUCIAL SCREWS

The invention relates to a device for referencing a fiducial implant and a device for referencing a fiducial implant for insertion into a portion of a body. The invention
5 also relates to a use of at least two fiducial implants suitable for insertion in a body and a use of at least one fiducial implant suitable for insertion into a body.

A problem is frequently encountered in Computer Assisted Surgery in that for instance a computer tomogram of the bones
10 or body parts to be treated is the starting point of the surgical intervention. It may be necessary to identify by position-finding a given point on the bone or body part associated with the surgical instruments and to compare its position with that of the identical point on the computer
15 tomogram.

To achieve minimal injury to the soft parts around the bone, the bone, or also, for instance, a vertebra, shall be operated on without exposing large surfaces of the parts to be treated (minimal invasive technology). Computer assisted
20 surgery is appropriate in this respect. To register the patient's system of coordinates in the operating room as determined by the dynamic reference base of the position finding system with the system of coordinates of the previously recorded tomographic image data, a transformation
25 of coordinates, called "matching", must be carried out.

A more comprehensive description of computer assisted surgery including a matching algorithm suitable for such transformation of coordinates is given in L. P. NOLTE ET AL, CLINICAL EVALUATION OF A SYSTEM FOR PRECISION ENHANCEMENT IN
30 SPINE SURGERY, CLINICAL BIOMECHANICS, 1995, VOL. 10, No. 6, PP 293-303.

One way to match the coordinate system of the patient in the operating room to the patient's image coordinate system is to use mechanical scanning devices such as are illustratively described in the US patent 5,383,454 (Buchholz). However these
5 known procedures are exceedingly time-consuming and presently only of obsolete accuracy.

Another way of matching the patient's system of coordinates in the operating room with the system of coordinates of the image consist in identifying predetermined
10 points using anatomical reference points. Where the body parts are only little exposed, this method also is difficult because of restricted visual access. Frequently an endoscope must be used.

A device for the preoperative determination of position data of parts of endoprotheses of a intermediate bone joint relative to the bone which form the intermediate bone joint is disclosed in DE 29 704 393 AESCULAP. This known device comprises a measuring device for the determination of the position of marking elements within a three-dimensional system
20 of coordinates, a data processing unit and a marking element each for the two bones forming the bone joint. These marking elements consist of a foot screwable into a bone each in the form of a bone screw and a T-shaped top body comprising for markers being apart from each other.

25 In another method to register the systems of coordinates, so-called fiducial implants are used to unequivocally identify the reference points. Such a method and appropriate apparatus are described in US 4,945,914 (Allen). This method includes the implantation of at least 4 spatially related fiducials.

30 All these known methods share the drawback of being fairly time-consuming.

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The objective of the invention is palliation. Its purpose is to create a device and method allowing to create a spatial relationship, for reference points on fiducial screws, between their positions in the physical body's system of coordinates and the positions of the identical reference points in the system of coordinates of the image, while entailing only little injury to the soft tissue around the bone(s) (minimal invasive technology). The purpose of the device is to define two reference points on a fiducial screw, and as a result the method requires only two implanted fiducial screws. Furthermore the image may be an x-ray or a digitally stored computer tomogram.

In accordance with one aspect of the present invention, the invention solves the problem using a device for referencing a fiducial implant, comprising: a fiducial implant for insertion into a portion of a body, the implant having first and second spaced apart reference points and a head, the head and the reference points having a known spatial relationship; a pointer having a distal pointer end and at least three emitters configured to emit radiation, the distal pointer end and the at least three emitters having a known spatial relationship; a position finder comprising at least two detectors configured to detect the radiation whereby the position of the at least three emitters in three-dimensional space can be determined; and wherein the head of the implant and the distal pointer end are configured to removably and reproducibly mate to provide a known spatial relationship between the first and second spaced apart reference points of the fiducial implant and the distal pointer end to allow the position of the first and second spaced apart reference points in three dimensional space to be determined.

In accordance with an alternate aspect of the present invention, the invention solves the problem using a device for

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referencing a fiducial implant for insertion into a portion of a body, the implant having first and second spaced apart reference points and a head, the head and the reference points having a known spatial relationship, the device comprising: a pointer having a distal pointer end and at least three emitters configured to emit radiation, the distal pointer end and the at least three emitters having a known spatial relationship; a position finder comprising at least two detectors configured to detect the radiation whereby the position of the at least three emitters in three-dimensional space can be determined; and wherein the head of the implant and the distal pointer end are configured to removably and reproducibly mate to provide a known spatial relationship between the first and second spaced apart reference points of the fiducial implant and the distal pointer end to allow the position of the first and second spaced apart reference points in three dimensional space to be determined.

In accordance with an alternate aspect of the present invention, there is provided a use of at least two fiducial implants suitable for insertion in a body, each fiducial implant providing at least two spaced apart reference points, for determining the position in three-dimensional space of the at least two spaced apart reference points of each of the at least two fiducial implants and determining the spatial relationship between the spaced apart reference points of the at least two fiducial implants.

In accordance with an alternate aspect of the present invention there is provided a use of at least one fiducial implant suitable for insertion into a body, the fiducial implant having at least two spaced apart reference points and a pointer suitable for associating with the fiducial implant, said pointer having at least three emitters configured to emit radiation, wherein the at least three emitters have a known

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spatial relationship and the fiducial implant and pointer are oriented along a longitudinal axis for determining the position in three-dimensional space of the at least two spaced apart reference points of the implant associated with the
5 pointer.

In a preferred embodiment of the device of the invention, a pointer filled with marker means is moved in a spatially precisely defined position and orientation relative a fiducial screw fitted with fixed reference points. One reference point
10 is the tip of the fiducial screw and the other reference point is the screw head. The pointer is positioned by inserting a tightly fitting pin at its front end into a corresponding aperture in the head of the fiducial screw. The aperture in the fiducial screw head and hence the pin then are concentric
15 with the longitudinal axis of the fiducial screw , the pin in turn being concentric with the pointer. Accordingly the pointer and the fiducial screw are located in an axis defined by the reference points on the fiducial screw. The pointer position is defined in the direction of this longitudinal axis
20 because the pointer stem adjoining the pin is of a larger diameter than the pin diameter and thereby abuts the screw head. For a given position of the marker means in the system of coordinates, the position of the reference points on the fiducial screw can therefore be ascertained in the
25 same system of coordinates. The marker means may be in the form of emitters/detectors emitting or detecting

electromagnetic or acoustic waves. Depending on the kind of emitters/detectors, the marker means position can be ascertained by an appropriate position detector.

The position detector also may be part of a CAS (computer assisted surgery) system and may include an image processing computer software.

5 The method of the invention to create a spatial relation between reference points is based on the concept that the bone-implanted fiducial screws can be recognized in a three-dimensional image for instance made by computer tomography or in a common x-ray of the bone. If the reference points on the fiducial screws are measured on the image in terms of a corresponding system of coordinates and if the reference points in the fiducial screws mounted on the physical body are measured by the device
10 of the invention in terms of another system of coordinates, then associating the positions of the reference points in the image with those on the real body makes it possible that any point on the image can be related by a coordinate transformation to the corresponding point in the physical bone, and vice-versa. By means of the method and the device of the invention, the registration or matching of the systems of coordinates can be implemented by only two fiducial screws implanted in the body.

15 Ordinarily the term "fiducial matching" denotes the creation of the spatial relation of reference points on fiducial screws between their positions in the system of coordinates of the physical body and the positions of the identical reference points in the system of coordinates in the image.

Further advantageous embodiments of the invention are defined in the dependent claims.

20 Essentially the advantages offered by the invention are that thanks to the device of the invention and using the method of the invention, it suffices to implant only two fiducial screws to fiducially match the coordinate system of the image to the actual system of coordinates, and in that the bone segment receiving the implanted fiducial screws need be exposed only minimally (minimal invasive technology).

The invention and its further developments are elucidated below in relation to several embodiments partly shown in schematic manner.

25 **Fig. 1** is a perspective of an embodiment of the device of the invention, and

Fig. 2 is a partly sectional side view of an embodiment of the device of the invention.

The embodiment of the device of the invention shown in Figs. 1 and 2 comprises a fiducial screw 2 of longitudinal axis 9 and a pointer 3 having a front end 15, a rear end 16, a cylindrical stem 4 and a grip 5. A cylindrical pin 7 is present at the front end 15, opposite the grip 5, of the pointer 3 and is

insertable concentrically as a snug fit into the aperture 12 present in the head 22 of the fiducial screw 2 to receive a tool for screwing in or out the fiducial screw 2. The cross-section of the pin 7 is less than that of the stem 4 of the pointer 3 and as a result the axial position of the inserted pointer 3 is rigorously defined because the shoulder 17 rests on the rear end 13 preferably perpendicular to the longitudinal axis 9 of the fiducial screw 2. This aperture 12 concentric with the longitudinal axis 9 in the head 22 of the fiducial screw 2 may be internally threaded or fitted with a hexagonal socket. If this aperture 12 is internally threaded, the pin 7 of the pointer 3 may be threaded externally to allow a rigid, detachable connection between the pointer 3 and the fiducial screw 2. Because of this concentric assembly of the pointer 3 and the fiducial screw 2, the longitudinal pointer axis 9 coincides with the longitudinal axis 9 of the fiducial screw 2, and as a result the direction of the cylindrical pointer 3 is defined relative to the fiducial screw 2. Three LEDs (light emitting diodes) 6 are mounted at the rear end 16 of the pointer 3 in such manner that they are in one plane 18 which is perpendicular to the longitudinal axis 9 of the pointer 3 and may be located at the rear end 16 of this pointer 3. The LEDs are not collinear.

As shown in Fig. 2, the length (x) between the front end 14 forming one reference point and the head 22 of the fiducial screw 2 forming the second reference point and the length y between the shoulder 17 and the plane 18 containing the LEDs 6 are precisely determined. Knowing the position of the LEDs 6 relative to a system of coordinates in the room, further the coaxial and concentric alignment of the longitudinal axis 9 of the pointer 3 with the longitudinal axis 9 of the fiducial screw 2 and the axially defined position of the pointer 3 relative to the fiducial screw 2 by means of the shoulder 17 at the stem 4 of the pointer 3 abutting the screw head 22, it is thereby possible to ascertain the locations of the reference points defined by the front end 14 and the screw head 22 in the same system of coordinates in the room.

In the embodiment of the device of the invention shown in Fig. 1, the LEDs 6 may be powered by a cable 8. Other power supplies such as plain or rechargeable batteries also are possible. If the at least three non-collinear electromagnetic or acoustic wave-generating means 19 are LEDs 6 as shown in the embodiment of the invention of Figs. 1 and 2, the spatial position finding by the LEDs 6 relative to a system of coordinates can be implemented using commercial optical position finders. Such an optical position finder is on the market as OPTOTRAK™.

When the fiducial screw 2 of Fig. 1 is screwed into a bone 1, the sites of the reference points defined by the front end 14 and the screw head 22 of the physical fiducial screws 2 can be registered, i.e. matched in the two particular systems of coordinates with the sites of same reference points recorded at another time for instance by computer tomography in a 3D image

5 Moreover an embodiment of the device of the invention additionally may comprise a position finder 24 which inside the room includes at least two sensors 23 detecting the electromagnetic or acoustic waves emitted by the means 19.

Claims

What is claimed is:

1. A device for referencing a fiducial implant, comprising: a fiducial implant for insertion into a portion of a body, the implant having first and second spaced apart reference points and a head, the head and the reference points having a known spatial relationship; a pointer having a distal pointer end and at least three emitters configured to emit radiation, the distal pointer end and the at least three emitters having a known spatial relationship; a position finder comprising at least two detectors configured to detect the radiation whereby the position of the at least three emitters in three-dimensional space can be determined; and wherein the head of the implant and the distal pointer end are configured to removably and reproducibly mate to provide a known spatial relationship between the first and second spaced apart reference points of the fiducial implant and the distal pointer end to allow the position of the first and second spaced apart reference points in three-dimensional space to be determined.

2. The device of claim 1, wherein the body is a bone, and further comprising a processor configured to perform a coordinate transformation to match the position of each reference point in three-dimensional space with a corresponding position of the respective reference point in a stored image of the bone.

3. The device of claim 2, further comprising at least a second fiducial implant for insertion in the bone, the second implant having a head and at least third and fourth reference points, wherein the head of the second implant and the distal pointer end are configured to removably and reproducibly mate to provide a known spatial relationship between the third and fourth reference points and the distal pointer end to allow

the position of the third and fourth reference points in three-dimensional space to be determined.

4. The device of claim 3, wherein the processor is configured to match the positions in three-dimensional space of the third and fourth reference points with the positions of the respective reference points in the stored image of the bone and further wherein the processor is configured to perform a coordinate transformation whereby the position of a selected point on the bone can be matched with the corresponding position of the selected point in the image of the bone.

5. The device of claim 1, wherein the head of the fiducial implant comprises a cavity and the distal pointer end of the pointer comprises a pin configured to be received within the cavity to provide the known spatial relationship between the reference points and the first end of the pointer.

6. The device of claim 5, wherein the distal pointer end of the pointer comprises a shoulder adjoining the pin, the shoulder having a diameter larger than a diameter of the pin and being configured to abut the head of the implant when the pin is received within the cavity.

7. The device of claim 6, wherein the fiducial implant is a fiducial screw and the pointer can be used to screw in or screw out the fiducial screw when the pin is received within the cavity.

8. The device of claim 1, wherein the radiation comprises electromagnetic radiation or acoustic waves.

9. The device of claim 1, wherein the fiducial implant and pointer are arranged along a longitudinal axis and the at least three emitters are arranged in a plane perpendicular to the longitudinal axis.

10. Use of at least two fiducial implants suitable for insertion in a body, each fiducial implant providing at least two spaced apart reference points, for determining the position in three-dimensional space of the at least two spaced apart reference points of each of the at least two fiducial implants and determining the spatial relationship between the spaced apart reference points of the at least two fiducial implants, wherein one of said fiducial implants is part of a device that further comprises a pointer having a distal end and at least three emitters configured to emit radiation, the distal end and the at least three emitters having a known spatial relationship, and a detector; wherein said distal end is configured for removable association with each of the fiducial implants individually to reproducibly provide a known spatial relationship between the reference points and the distal end and wherein said detector is for detecting radiation emitted from said emitters to determine the position of the at least three emitters in three-dimensional space to allow the position of each reference point in three-dimensional space to be determined.

11. The use according to claim 10, wherein the body is a bone.

12. The use according to claim 11, further comprising a use of at least one image showing the bone and at least two of the fiducial implants following insertion.

13. The use according to claim 12, wherein one of said fiducial implants is part of a device that further comprises a processor for performing a coordinate transformation to match the positions of the reference points in three-dimensional space with corresponding positions of the reference points in the image.

14. The use according to claim 13, wherein said image is a digitally recorded computer three-dimensional computer tomogram.

15. Use of at least one fiducial implant suitable for insertion into a body, the fiducial implant having at least two spaced apart reference points and a pointer suitable for associating with the fiducial implant, said pointer having at least three emitters configured to emit radiation, wherein the at least three emitters have a known spatial relationship and the fiducial implant and pointer are oriented along a longitudinal axis for determining the position in three-dimensional space of the at least two spaced apart reference points of the implant associated with the pointer.

16. The use according to claim 15, wherein the pointer has a distal end for association with one of the fiducial implants to removably and reproducibly provide a known spatial relationship between the spaced apart reference points of the implant associated with the distal end and the distal end for detecting the radiation to determine the position of the at least three emitters in three-dimensional space to allow the position of each spaced apart reference point of the implant associated with the distal end to be determined in three-dimensional space; wherein the association of each of the fiducial implants to be referenced may be repeated.

17. The use according to claim 15, wherein the body is a bone.

18. The use according to claim 17, further comprising a use of at least one image showing the bone and at least two of the fiducial implants following insertion.

19. The use according to claim 18, wherein said fiducial implant is part of a device that further comprises a processor

for performing a coordinate transformation to match the positions of the reference points in three-dimensional space with corresponding positions of the reference points in the image.

20. The device of claim 1, wherein the head of the fiducial implant is one of the first and second spaced apart reference points of the fiducial implant.

21. A device for referencing a fiducial implant for insertion into a portion of a body, the implant having first and second spaced apart reference points and a head, the head and the reference points having a known spatial relationship, the device comprising: a pointer having a distal pointer end and at least three emitters configured to emit radiation, the distal pointer end and the at least three emitters having a known spatial relationship; a position finder comprising at least two detectors configured to detect the radiation whereby the position of the at least three emitters in three-dimensional space can be determined; and wherein the head of the implant and the distal pointer end are configured to removably and reproducibly mate to provide a known spatial relationship between the first and second spaced apart reference points of the fiducial implant and the distal pointer end to allow the position of the first and second spaced apart reference points in three-dimensional space to be determined.

22. The device of claim 21, wherein the implant is a screw configured to be screwed into a bone.

23. The use according to claim 11, wherein at least one of the fiducial implants is a screw suitable for screwing the at least one screw into the bone.

24. The use according to claim 15, wherein the body is a bone and at least one of the fiducial implants is a screw suitable for screwing the at least one screw into the bone.

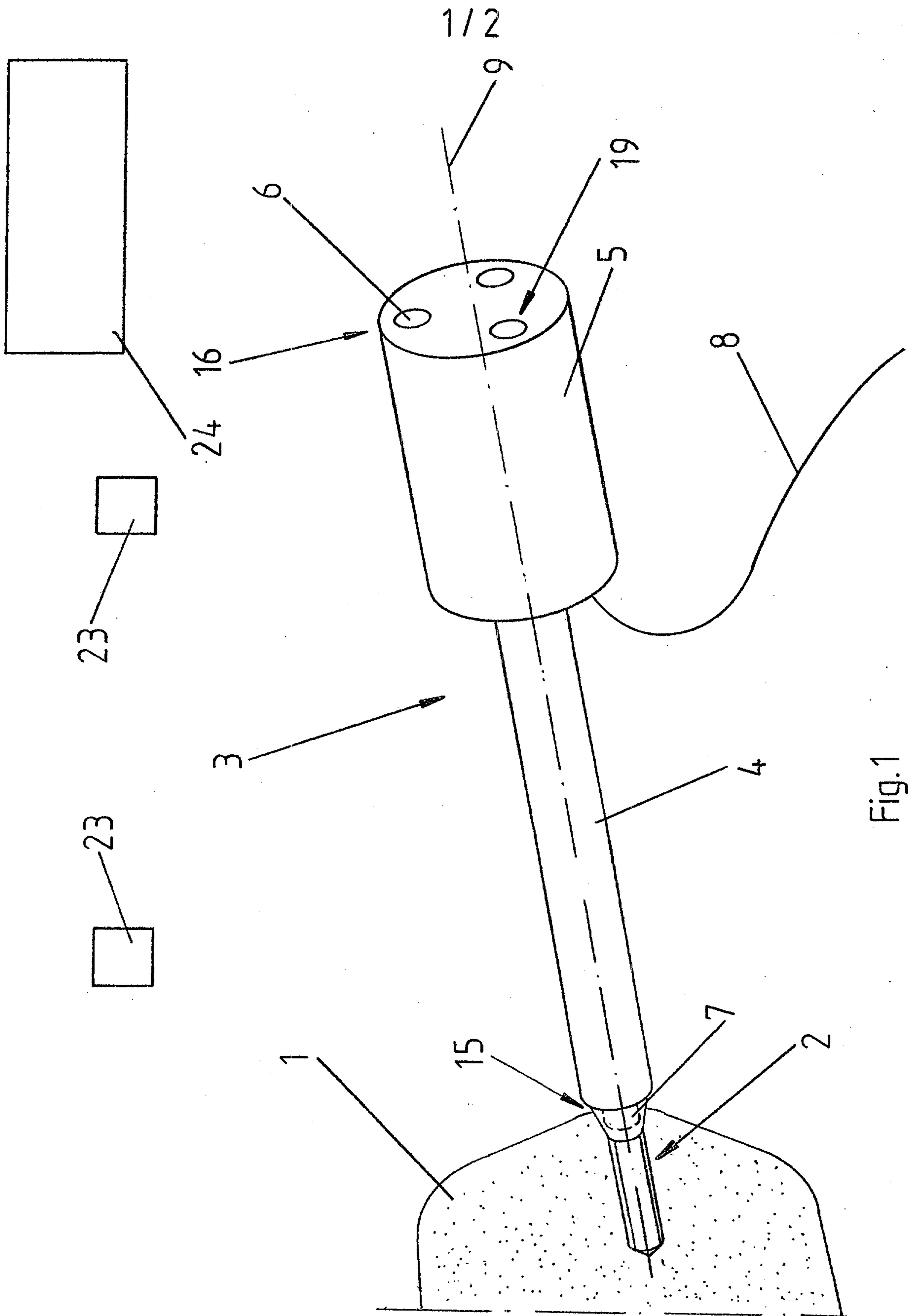


Fig.1

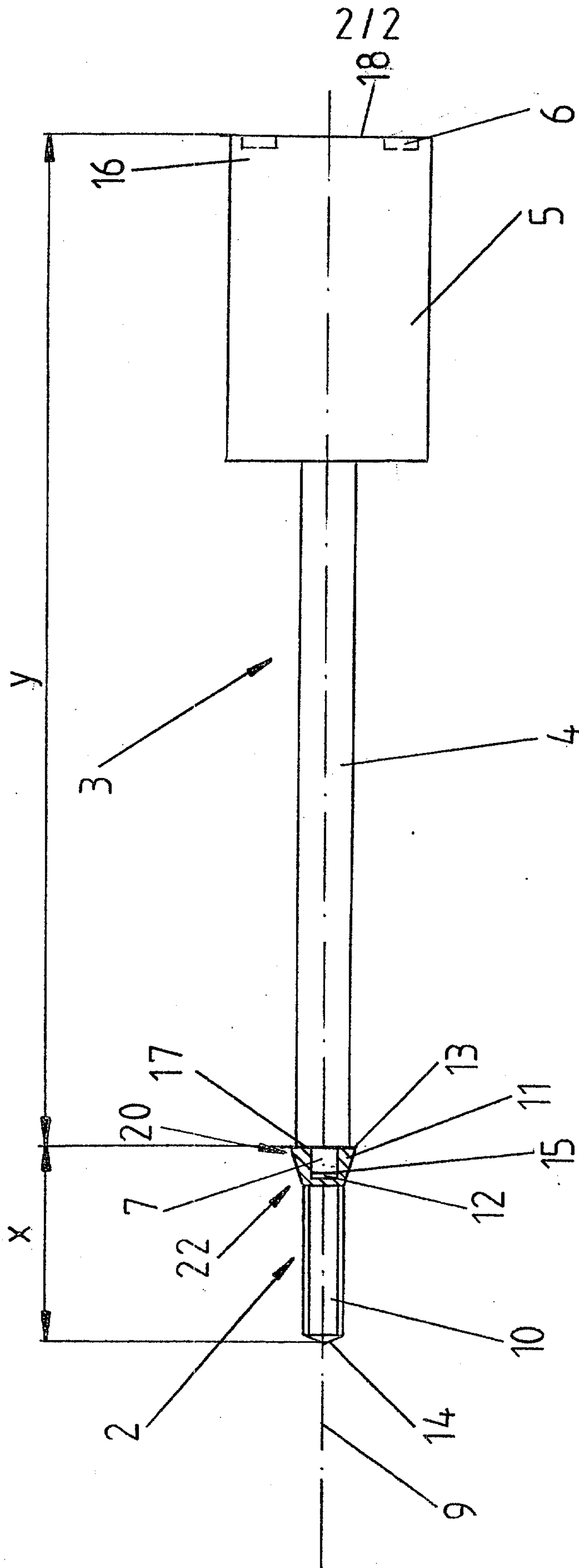


Fig. 2

