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(54) SYSTEM FOR THREE DIMENSIONAL MEASUREMENT OF FOOT ALIGNMENT

SYSTEM ZUR DREIDIMENSIONALEN MESSUNG DER FUSSAUSRICHTUNG

SYSTÈME POUR MESURE TRIDIMENSIONNELLE D'ALIGNEMENT DE PIED

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Description

Field of the Invention

[0001] The present invention is directed to a system for measuring foot-ankle three-dimensional weight-bearing alignment using multi-dimension (e.g., 3D) weight bearing radiographic data.

Background

[0002] Currently measurements of tibial-calcaneal or vertical-calcaneal alignment are performed using two-dimensional standard radiographs and applying various radiographic protocols, such as the long-leg view, Meary, Saltzman, or Cobey. See, for example, Mendicino, R. W., Catanzariti, A. R., John, S., Child, B. & Lamm, B. M., "Long leg calcaneal axial and hindfoot alignment radiographic views for frontal plane assessment," J. Am. Podiatr. Med. Assoc. 98, 75-78 (2008); Saltzman, C. L. & el-Khoury, G. Y., "The hindfoot alignment view," Foot Ankle Int. 16, 572-576 (1995); Strash, W. W. & Berardo, P., "Radiographic assessment of the hindfoot and ankle," Clin. Podiatr. Med. Surg. 21, 295-304, v (2004); and Tuijthof, G. J., Herder, J. L., Scholten, P. E., van Dijk, C. N. & Pistecky, P. V., "Measuring alignment of the hindfoot," J. Biomech. Eng. 126, 357-362 (2004). Each of these methods uses two dimensional data obtained from radiographic scan and bases all the foot ankle alignment assessments off of those scans. In each case, the protocols do not take into account the relation of the forefoot with the hindfoot. Instead, they only provide a measurement of the hind-foot-ankle-leg alignment. As such, it is not a complete-foot-ankle alignment measurement.

[0003] The inventors have determined that the existing methods' failure to take into account the measurement of the forefoot results in less precision due to poorly reproducible radiographic protocols. Also, since the prior methods rely solely on hindfoot measurement, the accuracy of the overall measurement geometrically depends on the rotation of the lower limb.

[0004] A need therefore exists for an improved method for providing foot-ankle alignment measurement.

Summary of the Invention

[0005] A system for determining alignment measurement of the foot and ankle, referred to as foot-ankle offset (FAO) based on utilization of three dimensional imaging and determination of a three dimensional foot alignment measurement referring to herein as the Torque Ankle Lever Arm System, (TALAS™). The system and related process uses medical imaging devices to obtain 3D coordinates for a set of anatomical landmarks and an algorithm generates a precise measure of human static ankle intrinsic lever arm for use in diagnostic and surgical planning processes.

[0006] The system is as defined in claim 1.

[0007] The ground plane is preferably determined using center points of the landmarks. A triangular pyramid may be configured as representative of the patient's foot with the vertical apex being the center of the talar dome and the base being the ground plane.

[0008] In an embodiment the system determines the center of each landmark by analyzing slices of the scanned data and determining the center of the tuberosity based on that analysis. Alternatively, a user may select the three dimensional center point of each landmark on a computer monitor depicting the scanned image.

[0009] The ground plane if preferably defined by a plane passing through the center points of the landmarks.

[0010] The present invention also includes a software program as defined by claim 9.

[0011] The foregoing and other features of the invention and advantages of the present invention will become more apparent in light of the following detailed description of the preferred embodiments, as illustrated in the accompanying figures. As will be realized, the invention is capable of modifications in various respects, all without departing from the invention. Accordingly, the drawings and the description are to be regarded as illustrative in nature, and not as restrictive.

Brief Description of the Drawings

[0012] For the purpose of illustrating the invention, the drawings show a form of the invention which is presently preferred. However, it should be understood that this invention is not limited to the precise arrangements and instrumentalities shown in the drawings.

Fig. 1 is a flowchart depicting one embodiment of the steps involved in the process for determining foot-ankle offset.

Fig. 2 is a graph depicting a measurement of the torque developed by body weight (gravity) and ground reaction force in the ankle coronal plane which includes a highest point on the talar dome.

Fig. 3 is a three dimensional graphical model of the foot-ankle alignment measurement.

Description of the Embodiments

[0013] Correct alignment is the main objective related to many orthopaedic surgical trauma and degenerative corrective procedures in the human body. It is well recognized that correct alignment improves joint pressure distribution, (see, for example, Fukuda, T., Haddad, S. L., Ren, Y. & Zhang, L. Q., "Impact of talar component rotation on contact pressure after total ankle arthroplasty: a cadaveric study," Foot Ankle Int. 31, 404-411 (2010); Liau, J. J., Cheng, C. K., Huang, C. H. & Lo, W. H., "The effect of malalignment on stresses in polyethylene component of total knee prostheses--a finite element analysis," Clin. Biomech. (Bristol, Avon) 17, 140-146 (2002); and Werner, F. W., Ayers, D. C., Maletsky, L. P. & Rullkoetter, P. J., "The effect of valgus/varus malalignment on load distribution in total knee replacements," J. Biomech. 38, 349-355 (2005)) and ligament tension and muscle function[14] (see, Van Bergeyk, A. B., Younger, A. & Carson, B., "CT analysis of hindfoot alignment in chronic lateral ankle instability," Foot Ankle Int. 23, 37-42 (2002).) In turn, this prevents early joint degeneration (arthrosis), which is a major public health issue, leading to pain and disability. (See, Khan, F. A. et al., "Effect of local alignment on compartmental patterns of knee osteoarthritis," J. Bone. Joint Surg. Am. 90, 1961-1969 (2008); and Werner, F. W., Ayers, D. C., Maletsky, L. P. & Rullkoetter, P. J., "The effect of valgus/varus malalignment on load distribution in total knee replacements," J. Biomech. 38, 349-355 (2005).)

[0014] In the native foot and ankle, disturbed alignment has proven to increase the rate of arthrosis, ankle instability. See, Child, B. J., Hix, J., Catanzariti, A. R., Mendicino, R. W. & Saltrick, K., "The effect of hindfoot realignment in triple arthrodesis," J. Foot Ankle Surg. 48, 285-293 (2009); Fuchs, S., Sandmann, C., Skwara, A. & Chylarecki, C., "Quality of life 20 years after arthrodesis of the ankle. A study of adjacent joints," J. Bone. Joint Surg. Br. 85, 994-998 (2003); Guichet, J. M., Javed, A., Russell, J. & Saleh, M., "Effect of the foot on the mechanical alignment of the lower limbs," Clin. Orthop. Relat. Res., 193-201 (2003); and Van Bergeyk, A. B., Younger, A. & Carson, B., "CT analysis of hindfoot alignment in chronic lateral ankle instability," Foot Ankle Int. 23, 37-42 (2002). In the operated foot and ankle, disturbed alignment increases total ankle replacement failure rates through aseptic loosening, and the rate of peripheral joints arthrosis in ankle arthrodesis.

[0015] In the case of ankle and hindfoot surgery, the only measurement used for planning surgery today is the angle between the leg or the vertical and the hindfoot (calcaneus bone). See, for example, Haight, H. J., Dahm, D. L., Smith, J. & Krause, D. A., "Measuring standing hindfoot alignment: reliability of goniometric and visual measurements," Arch. Phys. Med. Rehabil. 86, 571-575 (2005); Magerkurth, O., Knupp, M., Ledermann, H. & Hintermann, B., "Evaluation of hindfoot dimensions: a radiological study," Foot Ankle Int. 27, 612-616 (2006); Mendicino, R. W., Catanzariti, A. R., John, S., Child, B. & Lamm, B. M., "Long leg calcaneal axial and hindfoot alignment radiographic views for frontal plane assessment," J. Am. Podiatr. Med. Assoc. 98, 75-78 (2008); Saltzman, C. L. & el-Khoury, G. Y., "The hindfoot alignment view," Foot Ankle Int. 16, 572-576 (1995); Strash, W. W. & Berardo, P., "Radiographic assessment of the hindfoot and ankle," Clin. Podiatr. Med. Surg. 21, 295-304, v (2004); and Tuijthof, G. J., Herder, J. L., Scholten, P. E., van Dijk, C. N. & Pistecky, P. V., "Measuring alignment of the hindfoot," J. Biomech. Eng.126, 357-362 (2004). This angle is in itself flawed since there have been many different descriptions, all using different anatomical landmarks. Also, in many cases, measurements imply the use of external non-radiolucent markers, introducing another variable in the analysis, reducing precision and augmenting risk of error. Most important, depending on rotation of the limb, the value of hindfoot alignment varies considerably.

[0016] This implies that inevitably, a number of patients will either not be precisely assessed or not be corrected depending on measurement flaws. Of course, in a proportion of these cases, human medical intervention will be able, through experience, to counteract these effects. However, experience and literature show that in a number of cases, there are still surgical failures that are not explainable with current alignment measurements. See, Viste, A. et al., "Periprosthetic osteolysis after AES total ankle replacement: Conventional radiography versus CT-scan," Foot and Ankle Surgery: Official Journal of the European Society of Foot and Ankle Surgeons, 21, 164-170, doi:10.1016/j.fas.2014.11.002 (2015).

[0017] The inventors have previously published a study to alert the medical community on this matter. See, Lintz, F. et al., "Ground Reaction Force Calcaneal Offset: A new measurement of hindfoot alignment," Foot and Ankle Surgery: Official Journal of the European Society of Foot and Ankle Surgeons 18, 9-14, doi:10.1016/j.fas.2011.01.003 (2012). A primitive algorithm was devised which was based on the use of standard plain radiographs, taken at 90° angles. It enabled the inventors to validate the concept of the mechanical relationship between the hindfoot and forefoot and provide better results than the traditional measurement. However, the algorithm was only calculated in an "ideal", (theoretically) perfectly balanced foot and was still flawed when values diverged from this situation. Furthermore, since the required radiographic and data extraction protocol was complicated and time consuming, radiographers would have to be taught the protocol and, with so much manual human intervention involved, the reproducibility was questionable, and the whole process was not fit for daily clinical use.

[0018] The present invention provides a computer/software application which uses weight-bearing three dimension CT scan data to determine the foot-ankle offset. Specifically, one weight-bearing CT cone-beam scanner that is particularly useful in the present invention is the PedCAT® CT scanner sold by CurveBeam, LLC. However the present invention can also be used with standard radiographs, EOS imaging or other forms of weight bearing CT technology enabling image acquisition up to and above knee level, standard CT scanning machines with weight bearing simulation, and weight bearing MRI scanning machines. This tool is compatible for use with 4D imaging solutions that are currently being developed.

[0019] As mentioned above, the present invention measures the alignment of the foot using three dimensional weight-bearing data. Using that data, the foot ankle offset (FAO) is determined, replacing the old tibial-calcaneal angle. The following outlines the steps of the process that the system undertakes to achieve the FAO. However, this is not restrictive of the many measurements, called 3D-Biometrics, which will emerge from the use of the TALAS technology, based on the 3D measurement of offsets or angles between different landmarks in the foot and ankle.

[0020] Referring to the figures, the patient's foot is scanned (Step 100) using a weight-bearing CT scan and the raw data is stored. Step 200. The scan should be taken of the patient in neutral (normal standing) position. The program includes a mathematical algorithm to adjust the scanned data based on the positioning of the feet relative to the machine and each other in order to provide consistent data. The data is then analyzed to detect the 3D coordinates of specific anatomical landmarks in the foot. Step 300 Preferably those landmarks are the center of the first and fifth metatarsal bones heads (A and B, respectively) and the center of the greater tuberosity of the calcaneus (C), which are detected on the weight-bearing or ground plane. One method for determining this is to analyze slices of the scanned data until all three points (A, B, C) are detected in accordance with well-known techniques for point detection. That defines the ground plane. The center of the talar dome (D) is also detected. This is not restrictive of any future development of technology (such as automatic segmentation through clustering or machine learning) enabling a possibly more precise or more reproducible way to determine the landmarks. Also the acquisition of great quantities of data (big data) by this means, and the subsequent analysis of this data may result in selection of different or additional landmarks. Also, it is envisioned that the software can be modified to add more landmarks to the system so as to create a more complete analysis of the foot and ankle in order to encompass more conditions. For instance, landmarks can be added on each of the metatarsal bones to better analyze the structure of the forefoot.

[0021] Using these points, a triangular based pyramid is defined with the summit of the pyramid being the center of the talar dome (D). The system is preferably configured to automatically analyze the 3D data to determine these landmarks. However, it is also contemplated that the software could display the 3D data of the foot and ankle image on a computer screen and permit a physician or technician to manually select the landmark positions. The software may permit the user to rotate the image so as to allow for a more precise selection of the center point of the talar dome (D). Precise determination of these anatomical landmarks is important in order to obtain a high degree of intra and inter observer reproducibility. Future technological development and automation of the process will contribute to this.

[0022] The torque on the ankle is determined by the body weight (gravity) and ground reaction force acting on the ankle coronal plane through the talar dome. Since gravity is perpendicular to the ground plane, calculations are based on orthogonal projections of the talar dome on the ground plane. Using the 3D static model of the foot and the detected landmarks, the program calculates the anatomical offset or lever arm (D'F vector), which characterizes each patient's foot. Step 400. This is done by determining the orthogonal projection (D') of the center of the talus (D) on the ground plane (the plane upon which points A, B and C lie (Fig. 3) and which represent points on the ground upon which the patient's foot is standing). If desired, the ground plane can be adjusted to account for the offset from the true ground (bottom of the foot).

[0023] To determine point F, the system determines the midpoint (E) between points A and B, and then projects a line in the ground plane to point C. A line is then projected from point D' orthogonal to the line CE. Point F is located at the intersection of the line orthogonal to D' and line CE. Fig. 3.

[0024] As mentioned above, the vector D'F is the minimal ankle lever arm length and uniquely identifies a person's foot. To remove any pixel-size discrepancies, the length of the vector D'F is divided by the length of the line segment CE, which is representative of the overall foot length, and then multiplied by 100 to provide a percentage. This is the three dimensional foot ankle offset (3D FAO).

[0025] The present invention contemplates that, based on analysis of the feet of a significant portion of patients, a "normal" value of the offset can be determined. The 3D FAO of the person being analyzed can then be compared to the normal 3D FAO for determining potential foot/ankle issues. Step 500. A foot without any FAO issues should have a comparison to the "normal" that is close to zero or slightly negative. The system can visually depict on the patient's 3D FAO and the "normal" (which may include a Gaussian distribution around the "normal"). For example the patient's 3D FAO may be overlapped on top of the Gaussian distribution of the "normal", thus providing the physician and patient with a quick visual understanding of where the patient is relative to the norm. What is determined to be the "normal" may vary based on certain characteristics, including age or ethnicity.

[0026] The TALAS™ system can be used to not only detect preoperative issues, but can be used to provide a reliable means of simulating osteotomies and checking corrections post-operatively, or intra-operatively, should intra-operative 3D imaging and planning devices be available.

[0027] In one initial study using existing data, the inventors have been able to determine that the use of 3D data for measurement of foot-ankle alignment improves correlation coefficients between alignment values and real values from 0.78 to 0.93. The use of the TALAS™ system described above increased this coefficient from 0.93 to 0.99. Considering the number of foot and ankle alignment cases operated on each year in the world, the TALAS™ system may represent a health improvement for between 60 to 220 patients for every 1000 patients treated each year, either immediately or on a longer term, correlating with less time off work, less health costs, and less revision surgeries. Although the above discussion has explained the invention with respect to the analysis of the fore-foot, those skilled in the art would readily appreciate its applicability to mid-foot and hind-foot analysis also.

[0028] As discussed above, the TALAS™ procedure is preferably part of a software system which allows individual patient data, including the ankle offset calculation to be collected and stored for historical analysis, thus permitting tracking of a patient's development over time. Graphical depictions of the patient's development can be generated and displayed, providing a visual perception of the development.

[0029] The system or systems described herein may be implemented on any form of microprocessor. The system of the present invention may include a software program stored on the microprocessor and/or storage device (e.g., media). The method may be implemented through program code or program modules stored on a non-volatile computer-readable storage medium.

[0030] For the purposes of promoting an understanding of the principles of the invention, reference has been made to the preferred embodiments illustrated in the drawings, and specific language has been used to describe these embodiments. However, no limitation of the scope of the invention is intended by this specific language, and the invention should be construed to encompass all embodiments that would normally occur to one of ordinary skill in the art.

[0031] The particular implementations shown and described herein are illustrative examples of the invention and are not intended to otherwise limit the scope of the invention in any way. For the sake of brevity, conventional electronics, control systems, software development and other functional aspects of the systems (and components of the individual operating components of the systems) may not be described in detail.

[0032] Finally, the use of any and all examples, or exemplary language (e.g., "such as") provided herein, is intended merely to better illuminate the invention and does not pose a limitation on the scope of the invention unless otherwise claimed.

Claims

1. A system for determining the alignment measurement of the foot and ankle, the system comprising:

receiving data (200) representative of a three dimensional scanned image of a patient's foot and ankle while the patient was applying weight on the foot;
adjusting the scanned data to correlate the three dimensional location of the foot relative to a predetermined coordinate system;
detecting the three dimensional coordinates (300) associated with at least three predetermined landmarks on the patent's foot in the scanned image;
determining a ground plane in the scanned data;
determining a center of a talar dome in the scanned data; and
determining an ankle offset lever arm (400) from the set of landmarks and center of the talar dome;
wherein the landmarks include the first and fifth metatarsal bones in the foot and the greater tuberosity of the calcaneus, and wherein the system analyzes the scanned image using point detection to determine the approximate three-dimensional coordinates (300) of the center of each landmark;
characterized in that the system further comprises the step of receiving data representing a weight of the patient;
wherein the step of determining the ankle offset lever arm involves the steps of determining an ankle offset point on the ground plane that is an orthogonal projection from the center point of the talar dome to the ground plane, determining a forefoot center point on the ground plane that is the center between the center points of the landmarks for the first and fifth metatarsal bones, defining a line extending between the center point of the landmark of the greater tuberosity of the calcaneus to the forefoot center point, and wherein the ankle offset lever arm is the length of an orthogonal projection on the ground plane from the line to the ankle offset point; and
further comprising the step of determining the torque on the ankle by multiplying the weight of the patient times the length of the ankle offset lever arm.

2. A system for determining the alignment measurement according to claim 1, wherein the ground plane is determined using center points of the landmarks.

3. A system for determining the alignment measurement according to claim 1, further comprising the step of defining a triangular pyramid with the vertical apex being the center of the talar dome and the base being the ground plane.

4. A system for determining the alignment measurement according to claim 1, wherein the system determines the center of each landmark by analyzing slices of the scanned data and determining the center of the tuberosity based on that analysis.

5. A system for determining the alignment measurement according to claim 1, wherein the ground plane is defined by a plane passing through the center points of the landmarks.

6. A system for determining the alignment measurement according to claim 5, further comprising the step of defining a triangular pyramid with the vertical apex being the center of the talar dome and the base being the ground plane.

7. A system for determining the alignment measurement according to claim 1, wherein the system includes the step of allowing a user to select the three dimensional center point of each landmark on a computer monitor depicting the scanned image.

8. A system for determining the alignment measurement according to claim 7, wherein the system includes the step of allowing a user to rotate the scanned image on the monitor to facilitate location of the center point of each landmark.

9. A software program stored on a non-volatile computer-readable storage medium, the program including code programmed for determining the alignment measurement of the foot and ankle, the system comprising:

receiving data (200) representative of a three dimensional scanned image of a patient's foot and ankle while the patient was applying weight on the foot;
determining three dimensional coordinates (300) in the scanned image of centers of at least three of the first and fifth metatarsal bones and the greater tuberosity of the calcaneus;
determining a ground plane defined by the detected center points;
determining three dimensional coordinates in the scanned image of an approximate center of a talar dome; and
determining an ankle offset lever arm (400) **characterized by** determining an ankle offset point on the ground plane that is an orthogonal projection from the center of the talar dome to the ground plane, determining a forefoot midpoint on the ground plane that is located at a midpoint between the centers of the first and fifth metatarsal bones, defining a line extending between the center of the greater tuberosity of the calcaneus to the forefoot midpoint, and wherein the ankle offset lever arm is the length of an orthogonal projection on the ground plane from the line to the ankle offset point.

10. A program for determining the alignment measurement according to claim 9, the system further comprising the steps of receiving data representing a weight of the patient, and determining the torque on the ankle by multiplying the weight of the patient times the length of the ankle offset lever arm.

11. A program for determining the alignment measurement according to claim 10, the system further comprising the steps of defining the torque by the length between the forefoot midpoint and the center of the greater tuberosity of the calcaneus of the patient, and multiplying by 100 to provide a percentage foot ankle offset; and outputting the percentage.

Patentansprüche

1. Ein System zum Bestimmen der Ausrichtungsmessung des Fußes und des Sprunggelenks, wobei das System Folgendes beinhaltet:

Empfangen von Daten (200), die ein dreidimensionales gescanntes Bild des Fußes und des Sprunggelenks des Patienten wiedergeben, wobei der Patient Gewicht auf den Fuß aufbrachte;
Anpassen der gescannten Daten, um die dreidimensionale Position des Fußes in Bezug auf ein vorher festgelegtes Koordinatensystem abzugleichen;
Feststellen der dreidimensionalen Koordinaten (300), die mit mindestens drei vorher festgelegten Orientierungspunkten auf dem Fuß des Patienten in dem gescannten Bild assoziiert sind;
Bestimmen einer Grundebene in den gescannten Daten;
Bestimmen einer Mitte einer Sprungbeinrolle in den gescannten Daten; und
Bestimmen eines Sprunggelenkversatz-Hebelarms (400) aus dem Satz Orientierungspunkte und der Mitte der Sprungbeinrolle;
wobei die Orientierungspunkte den ersten und fünften Mittelfußknochen in dem Fuß und den Fersenbeinhöcker umfassen und wobei das System das gescannte Bild unter Verwendung von Punkterkennung analysiert, um die ungefähren dreidimensionalen Koordinaten (300) der Mitte jedes Orientierungspunkts zu bestimmen;
dadurch gekennzeichnet, dass das System ferner den Schritt des Empfangens von Daten, die ein Gewicht des Patienten wiedergeben, beinhaltet;
wobei der Schritt des Bestimmens des Sprunggelenkversatz-Hebelarms folgende Schritte einschließt: Bestimmen eines Sprunggelenkversatzpunkts auf der Grundebene, der eine senkrechte Projektion von dem Mittelpunkt der Sprungbeinrolle zu der Grundebene ist, Bestimmen eines Vorfußmittelpunkts auf der Grundebene, der die Mitte zwischen den Mittelpunkten der Orientierungspunkte für den ersten und fünften Mittelfußknochen ist, Definieren einer Linie, die sich von dem Mittelpunkt des Orientierungspunkts des Fersenbeinhöckers bis zu dem Vor-

fußmittelpunkt erstreckt, und wobei der Sprunggelenkversatz-Hebelarm die Länge einer senkrechten Projektion auf der Grundebene von der Linie zu dem Sprunggelenkversatzpunkt ist; und ferner beinhaltend den Schritt des Bestimmens des Drehmoments auf das Sprunggelenk durch Multiplizieren des Gewichts des Patienten mit der Länge des Sprunggelenkversatz-Hebelarms.

2. System zum Bestimmen der Ausrichtungsmessung gemäß Anspruch 1, wobei die Grundebene unter Verwendung von Mittelpunkten der Orientierungspunkte bestimmt wird.

3. System zum Bestimmen der Ausrichtungsmessung gemäß Anspruch 1, das ferner den Schritt des Definierens einer Dreieckspyramide, bei der die vertikale Spitze die Mitte der Sprungbeinrolle und die Grundfläche die Grundebene ist, beinhaltet.

4. System zum Bestimmen der Ausrichtungsmessung gemäß Anspruch 1, wobei das System die Mitte jedes Orientierungspunkts bestimmt, indem Schichten der gescannten Daten analysiert werden und die Mitte des Höckers basierend auf dieser Analyse bestimmt wird.

5. System zum Bestimmen der Ausrichtungsmessung gemäß Anspruch 1, wobei die Grundebene durch eine Ebene definiert wird, die durch die Mittelpunkte der Orientierungspunkte verläuft.

6. System zum Bestimmen der Ausrichtungsmessung gemäß Anspruch 5, das ferner folgenden Schritt beinhaltet: Definieren einer Dreieckspyramide, bei der die vertikale Spitze die Mitte der Sprungbeinrolle und die Grundfläche die Grundebene ist.

7. System zum Bestimmen der Ausrichtungsmessung gemäß Anspruch 1, wobei das System folgenden Schritt beinhaltet: Ermöglichen, dass ein Benutzer den dreidimensionalen Mittelpunkt jedes Orientierungspunkts auf einem Computerbildschirm, der das gescannte Bild anzeigt, auswählt.

8. System zum Bestimmen der Ausrichtungsmessung gemäß Anspruch 7, wobei das System folgenden Schritt beinhaltet: Ermöglichen, dass ein Benutzer das gescannte Bild auf dem Bildschirm dreht, um die Ortung des Mittelpunkts jedes Orientierungspunkts zu erleichtern.

9. Ein Softwareprogramm, das auf einem nicht flüchtigen computerlesbaren Speichermedium gespeichert ist, wobei das Programm Code umfasst, der zum Bestimmen der Ausrichtungsmessung des Fußes und des Sprunggelenks programmiert ist, wobei das System Folgendes beinhaltet:

Empfangen von Daten (200), die ein dreidimensionales gescanntes Bild des Fußes und des Sprunggelenks eines Patienten wiedergeben, wobei der Patient Gewicht auf den Fuß aufbrachte;
Bestimmen dreidimensionaler Koordinaten (300) in dem gescannten Bild der Mitten von mindestens drei des ersten und fünften Mittelfußknochens und des Fersenbeinhöckers;
Bestimmen einer Grundebene, die durch die festgestellten Mittelpunkte definiert wird; Bestimmen dreidimensionaler Koordinaten in dem gescannten Bild einer ungefähren Mitte einer Sprungbeinrolle; und
Bestimmen eines Sprunggelenkversatz-Hebelarms (400), **gekennzeichnet durch** das Bestimmen eines Sprunggelenkversatzpunkts auf der Grundebene, der eine senkrechte Projektion von der Mitte der Sprungbeinrolle zu der Grundebene ist, Bestimmen eines Vorfußmittelpunkts auf der Grundebene, der sich an einem mittleren Punkt zwischen den Mitten des ersten und fünften Mittelfußknochens befindet, Definieren einer Linie, die sich von der Mitte des Fersenbeinhöckers bis zu dem Vorfußmittelpunkt erstreckt, und wobei der Sprunggelenkversatz-Hebelarm die Länge einer senkrechten Projektion auf der Grundebene von der Linie zu dem Sprunggelenkversatzpunkt ist.

10. Programm zum Bestimmen der Ausrichtungsmessung gemäß Anspruch 9, wobei das System ferner folgende Schritte beinhaltet: Empfangen von Daten, die ein Gewicht des Patienten wiedergeben und Bestimmen des Drehmoments auf das Sprunggelenk durch Multiplizieren des Gewichts des Patienten mit der Länge des Sprunggelenkversatz-Hebelarms.

11. Programm zum Bestimmen der Ausrichtungsmessung gemäß Anspruch 10, wobei das System ferner folgende Schritte beinhaltet: Definieren des Drehmoments durch die Länge zwischen dem Vorfußmittelpunkt und der Mitte des Fersenbeinhöckers des Patienten und Multiplizieren mit 100, um einen prozentualen Fuß-Sprunggelenk-Versatz bereitzustellen; und Ausgeben der Prozentangabe.

Revendications

1. Un système pour déterminer la mesure d'alignement du pied et de la cheville, le système comprenant :

la réception de données (200) représentatives d'une image tridimensionnelle obtenue par balayage du pied et de la cheville d'un patient alors

que le patient était en appui sur le pied ;
l'ajustement des données obtenues par balayage afin de corréler l'emplacement tridimensionnel du pied relativement à un système de coordonnées prédéterminées ;
la détection des coordonnées tridimensionnelles (300) associées à au moins trois points de repère prédéterminés sur le pied du patient dans l'image obtenue par balayage ;
la détermination d'un plan de sol dans les données obtenues par balayage ;
la détermination d'un centre d'un dôme du talus dans les données obtenues par balayage ; et
la détermination d'un bras de levier de décalage de cheville (400) à partir de l'ensemble de points de repère et du centre du dôme du talus ;
dans lequel les points de repère incluent les premier et cinquième os métatarsiens dans le pied et la grosse tubérosité du calcanéus, et dans lequel le système analyse l'image obtenue par balayage en utilisant la détection de points afin de déterminer les coordonnées tridimensionnelles (300) approximatives du centre de chaque point de repère ;
caractérisé en ce que le système comprend en sus l'étape de réception de données représentant un poids du patient ;
dans lequel l'étape de détermination du bras de levier de décalage de cheville implique les étapes de détermination d'un point de décalage de cheville sur le plan de sol qui est une projection orthogonale du point central du dôme du talus jusqu'au plan de sol, de détermination d'un point central d'avant-pied sur le plan de sol qui est le centre entre les points centraux des points de repère pour les premier et cinquième os métatarsiens, de définition d'une ligne s'étendant entre le point central du point de repère de la grosse tubérosité du calcanéus et le point central de l'avant-pied, et dans lequel le bras de levier de décalage de cheville est la longueur d'une projection orthogonale sur le plan de sol de cette ligne jusqu'au point de décalage de cheville ; et comprenant en sus l'étape de détermination du couple sur la cheville en multipliant le poids du patient par la longueur du bras de levier de décalage de cheville.

2. Un système pour déterminer la mesure d'alignement selon la revendication 1, dans lequel le plan de sol est déterminé en utilisant des points centraux des points de repère.

3. Un système pour déterminer la mesure d'alignement selon la revendication 1, comprenant en sus l'étape de définition d'une pyramide triangulaire dont l'apex vertical est le centre du dôme du talus et la base est le plan de sol.

4. Un système pour déterminer la mesure d'alignement selon la revendication 1, le système déterminant le centre de chaque point de repère en analysant des tranches des données obtenues par balayage et en déterminant le centre de la tubérosité sur la base de cette analyse.

5. Un système pour déterminer la mesure d'alignement selon la revendication 1, dans lequel le plan de sol est défini par un plan passant par les points centraux des points de repère.

6. Un système pour déterminer la mesure d'alignement selon la revendication 5, comprenant en sus l'étape de définition d'une pyramide triangulaire dont l'apex vertical est le centre du dôme du talus et la base est le plan de sol.

7. Un système pour déterminer la mesure d'alignement selon la revendication 1, le système incluant l'étape consistant à permettre à un utilisateur de sélectionner le point central tridimensionnel de chaque point de repère sur un écran d'ordinateur affichant l'image obtenue par balayage.

8. Un système pour déterminer la mesure d'alignement selon la revendication 7, le système incluant l'étape consistant à permettre à un utilisateur de faire tourner l'image obtenue par balayage sur l'écran afin de faciliter la localisation du point central de chaque point de repère.

9. Un programme de logiciel stocké sur un support de stockage lisible par ordinateur non-volatile, le programme incluant un code programmé pour déterminer la mesure d'alignement du pied et de la cheville, le système comprenant :

la réception de données (200) représentatives d'une image tridimensionnelle obtenue par balayage du pied et de la cheville d'un patient alors que le patient était en appui sur le pied ;
la détermination de coordonnées tridimensionnelles (300) dans l'image obtenue par balayage de centres d'au moins trois points parmi les premier et cinquième os métatarsiens et la grosse tubérosité du calcanéus ;
la détermination d'un plan de sol défini par les points centraux détectés ;
la détermination de coordonnées tridimensionnelles dans l'image obtenue par balayage d'un centre approximatif d'un dôme du talus ; et
la détermination d'un bras de levier de décalage de cheville (400) **caractérisée par** la détermination d'un point de décalage de cheville sur le plan de sol qui est une projection orthogonale du centre du dôme du talus jusqu'au plan de sol,
la détermination d'un point médian d'avant-pied

sur le plan de sol qui est situé au niveau d'un point médian entre les centres des premier et cinquième os métatarsiens, la définition d'une ligne s'étendant entre le centre de la grosse tubérosité du calcanéus et le point médian de l'avant-pied, et dans lequel le bras de levier de décalage de cheville est la longueur d'une projection orthogonale sur le plan de sol de cette ligne jusqu'au point de décalage de cheville.

10. Un programme pour déterminer la mesure d'alignement selon la revendication 9, le système comprenant en sus les étapes de réception de données représentant un poids du patient, et de détermination du couple sur la cheville en multipliant le poids du patient par la longueur du bras de levier de décalage de cheville.

11. Un programme pour déterminer la mesure d'alignement selon la revendication 10, le système comprenant en sus les étapes de définition du couple par la longueur entre le point médian de l'avant-pied et le centre de la grosse tubérosité du calcanéus du patient, et de multiplication par 100 afin d'obtenir un pourcentage de décalage pied-cheville ; et de sortie du pourcentage.

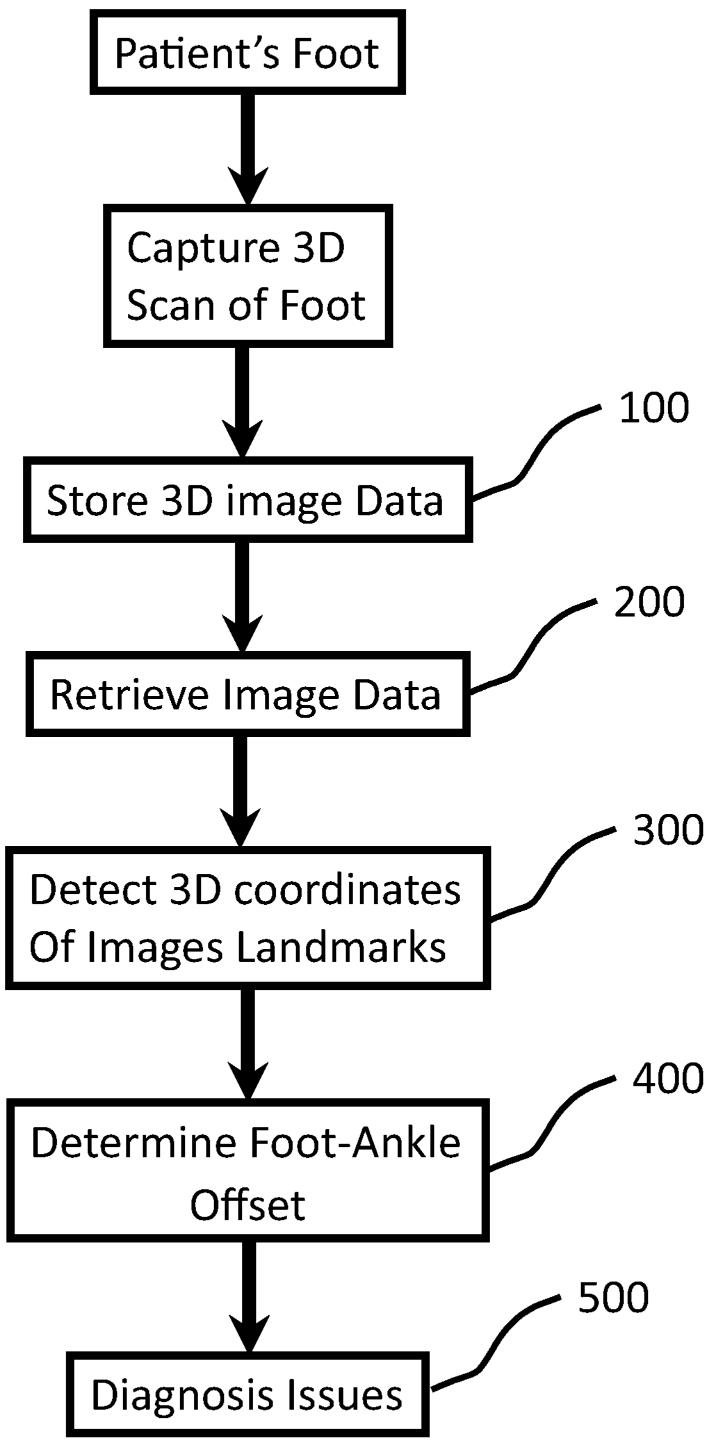
Patient's Foot
Capture 3D Scan of Foot
Store 3D image Data
100
Retrieve Image Data
200
Detect 3D coordinates Of Images Landmarks
300
Determine Foot-Ankle Offset
400
Diagnosis Issues
500

FIG. 1

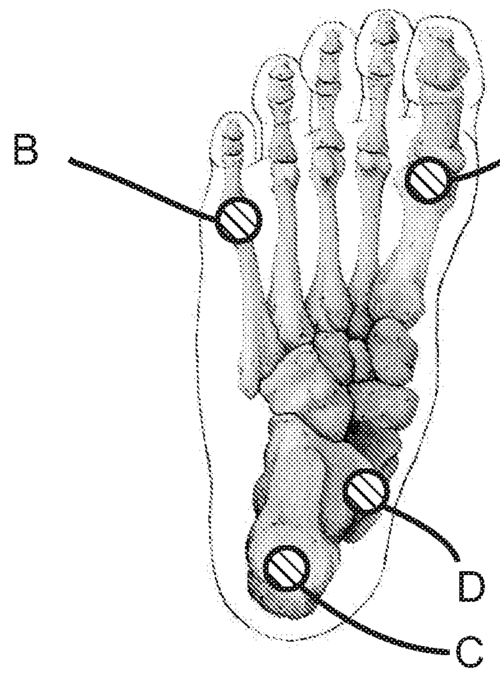

FIG. 2A

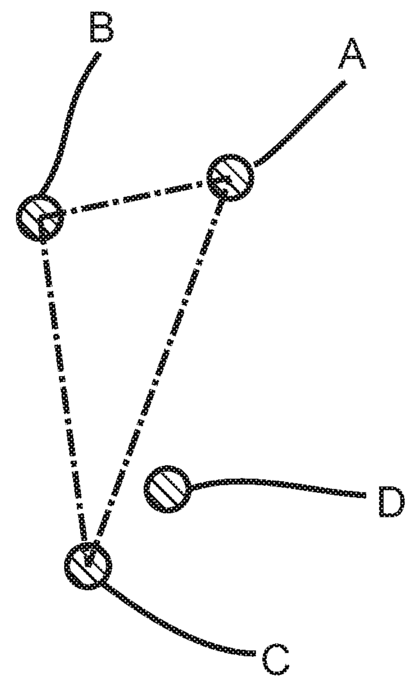

FIG. 2B

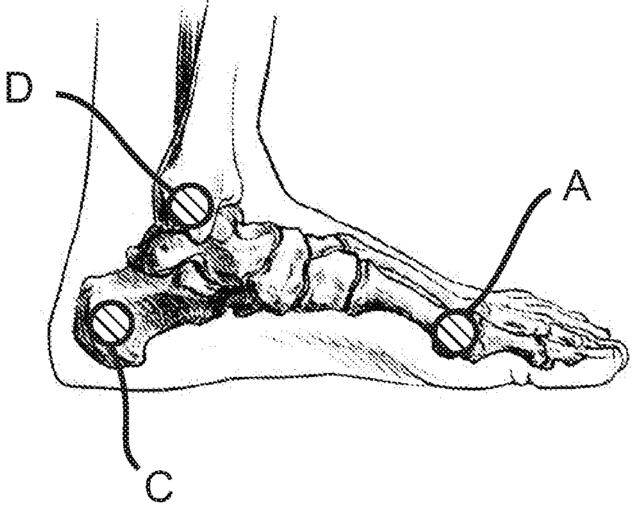

FIG. 3A

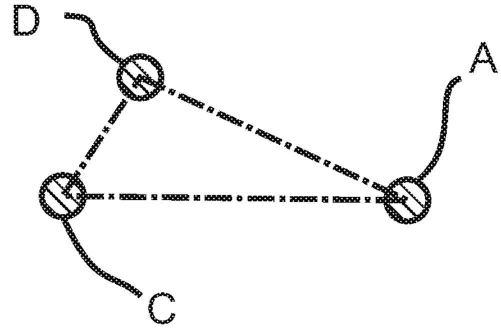

FIG. 3B

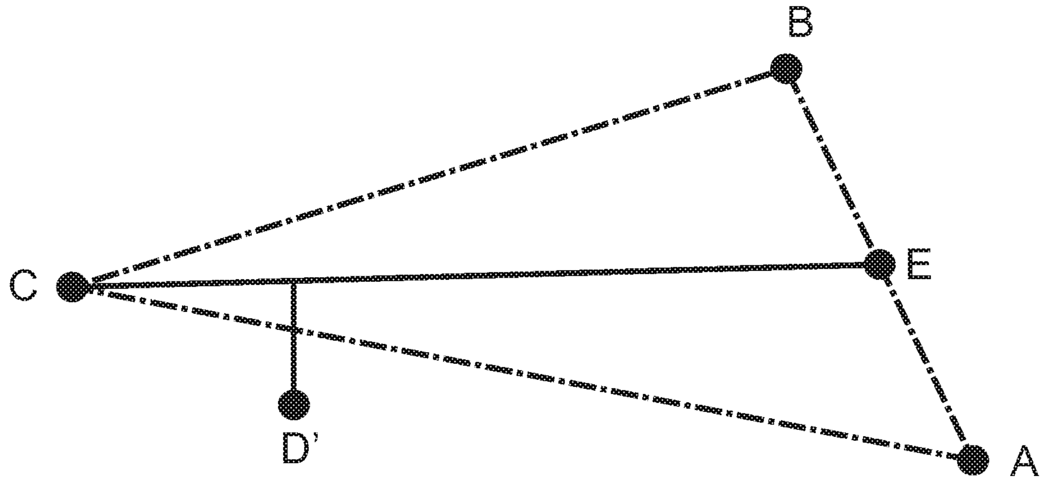

FIG.4

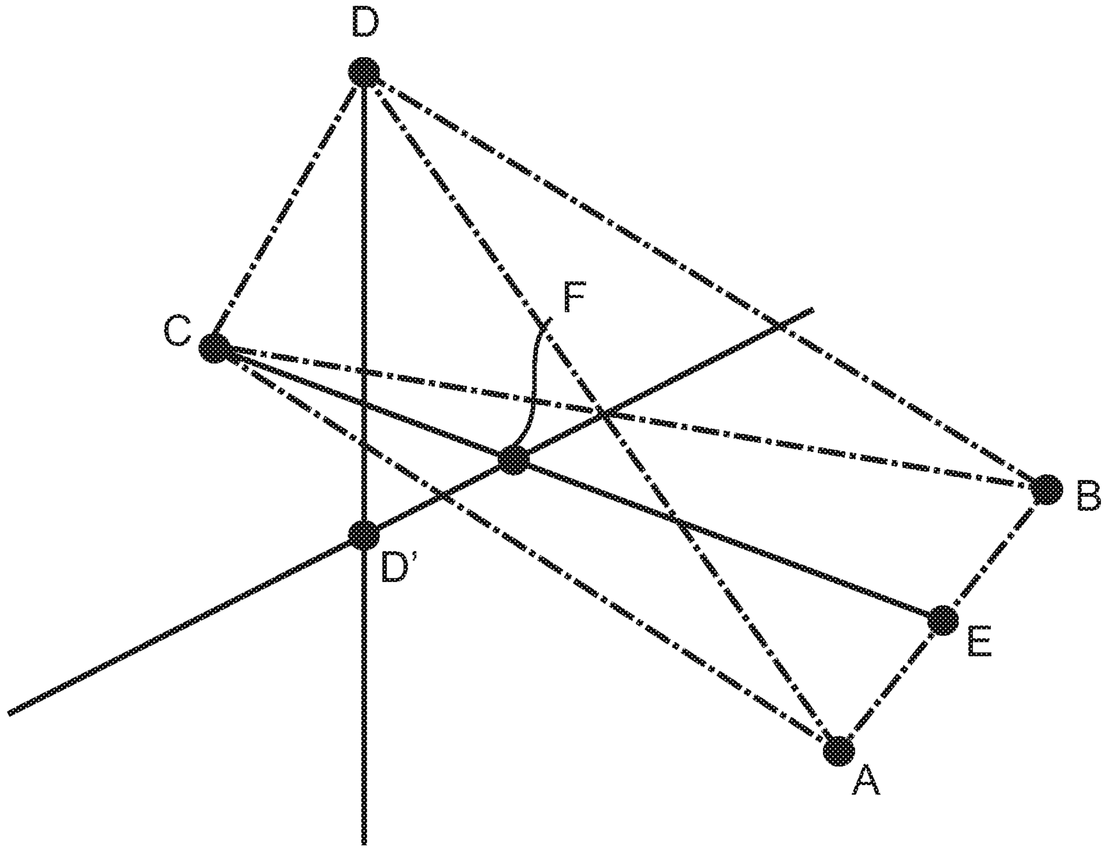

FIG. 5

REFERENCES CITED IN THE DESCRIPTION

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专利名称(译)	三维脚位测量系统		
公开(公告)号	[EP3361949B1](#)	公开(公告)日	2020-06-17
申请号	EP2016856261	申请日	2016-10-14
[标]申请(专利权)人(译)	弯曲束有限责任公司		
申请(专利权)人(译)	CURVEBEAM LLC		
当前申请(专利权)人(译)	CURVEBEAM LLC		
[标]发明人	LINTZ FRANCOIS L A LONG GUY D C WINSON IAN G MUNDRY UWE HANS		
发明人	LINTZ, FRANCOIS, L.A. LONG, GUY, D.C. WINSON, IAN, G. MUNDRY, UWE, HANS		
IPC分类号	G06T7/73 A61B5/00 A61B6/03 A61B6/00		
CPC分类号	A61B5/4595 A61B6/032 A61B6/505 A61B2562/17 A61B2576/02 G06T7/73 G06T2207/10081 G16H30/40 A61B5/0064 A61B5/1074 A61B5/1079		
代理机构(译)	MURGITROYD & COMPANY		
优先权	62/241513 2015-10-14 US		
其他公开文献	EP3361949A4 EP3361949A1		
外部链接	[Espacenet](#)		

摘要(译)

公开了一种用于确定脚和脚踝的对准度的系统。 该系统使用代表患者脚部重量的三维扫描图像的数据。 接下来，系统在扫描的图像中检测与专利的脚上的至少三个预定地标相关联的三维坐标。 使用预定的界标确定接地平面。 在扫描的数据中确定距骨圆顶的中心。 脚踝偏移杠杆臂id由一组距骨和距骨圆顶的中心确定。

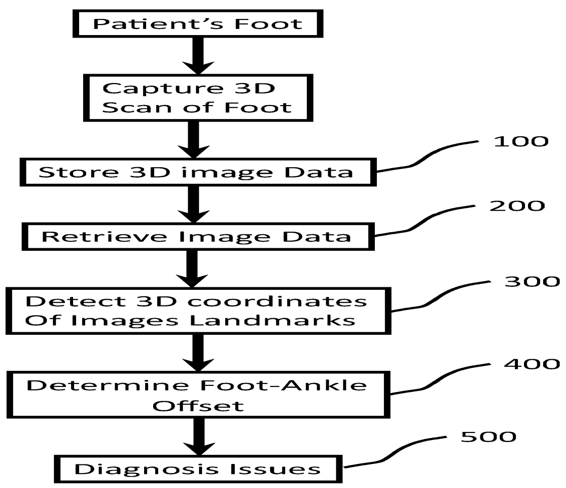

FIG. 1