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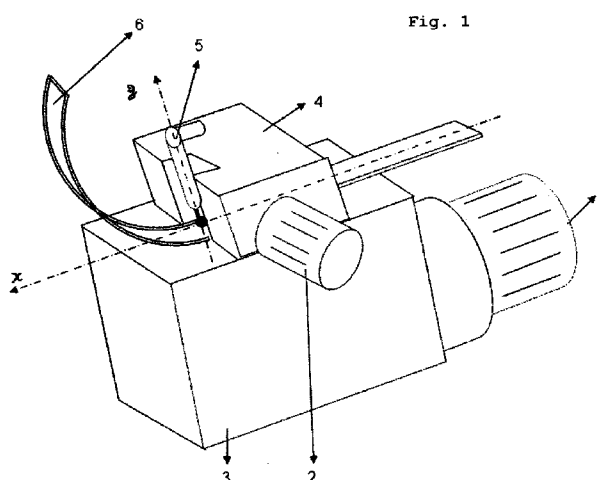
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(54) Title: SYSTEM FOR AUTOMATIC AND PERSONALIZED MODELLING/BENDING OF SURGICAL PROSTHESIS FOR CORRECTION OF PECTUS EXCAVATUM BASED ON PRE-SURGICAL IMAGING INFORMATION



(57) Abstract: The present invention concerns a modelling/bending system of surgical prosthesis (6) used in the correction of pectus excavatum, allowing its pre-operative personalization according to the thoracic morphology of each patient. Based on the information of the thoracic CT-scan, the system allows the application of a personalized prosthesis, giving way for a significant reduction of the surgery duration, and still makes it possible for the patient to have a virtual perspective of the foreseen post-operative result. The system includes the following steps: recognizing data from systems of medical imaging; setting a virtual personalized model of surgical prosthesis; pre-operative simulation of the predictable final result of the surgical intervention; sending control points to the controller (9) using local- or remote communication via web; automatic initial positioning of the surgical prosthesis in the desired position; automatic and mechanical bending of surgical prosthesis (6) with real time monitoring and control.

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**SYSTEM FOR AUTOMATIC AND PERSONALIZED MODELLING/BENDING OF
SURGICAL PROSTHESIS FOR CORRECTION OF PECTUS EXCAVATUM
BASED ON PRE-SURGICAL IMAGING INFORMATION**

Scope of the invention

The present invention was conceived to optimize the personalized modelling and bending of thoracic prosthesis to apply in the correction of *Pectus Excavatum*.

State of the art

Pectus excavatum is a deformity of the thoracic wall that, in a high percentage of cases, demands surgical correction. The classic surgical technique, assigned as Ravitch technique was, in the last decade, gradually substituted for surgical techniques that involve the placement of a convex thoracic prosthesis in sub-sternal position, initially described by Donald Nuss (US6024759). Briefly, the surgical technique consists of placing thoracic prosthesis in sub-sternal position through bilateral cutaneous incisions in the lateral thoracic wall (Nuss et al, J Pediatr Surg 1998). This technique has shown to be less aggressive, faster to execute and allows better cosmetic results. However, this technique estimates the thoracic application of one prosthesis that has to be modelled/bent in accordance with the thoracic morphology of each patient. Such is fulfilled per operatively and manually following the form of a mould generated during the surgical procedure. This procedure is slow, fastidious for the surgical team and leaves imperfections, many times, in the surface of the prosthesis. The main imperfections are the non uniform strength distribution of the prosthesis in

the support area (ribs), which concern initial discomfort thus increasing the adaptation time of the patient to the prosthesis. On the other hand, one third of the surgical time of the Nuss technique is dedicated to the modelling/bending of this prosthesis.

The present invention minimizes the previously cited inconveniences. In the pre-operative study of this type of patients, it is routine, to perform some other complementary examinations to reach the diagnosis, such as a CT-scan of the thoracic wall. The equipment herein described allows, on the basis of the information of the thoracic CT-Scan, to select the size, and automatically model/fold pre-operatively the thoracic prosthesis to apply. Such, allows the application of a personalized prosthesis which makes possible that the application of the forces in the zone of support of surgical prosthesis to be uniformly distributed, attenuating in such a way, the discomfort initially provoked and therefore shortening the period of adaptation to the same one. One should also enhance the significant shortening of the duration of the surgery, and the possibility of the patient having a virtual perspective of the post-operative result foreseen before the surgical intervention.

The use of systems of medical imagiology for the attainment of models of reference of prosthesis is already described for particular cases, for example: production of active biological prosthesis for the reconstruction of bone tissue (CA2561727); drawing and production to the measure of surgical tool-guide for the implantation of bone prosthesis (US2005148843); attainment of prosthesis geometry of spinal disc (WO0180786). The system herein presented stands out by

the particular application in modelling/bending of prosthesis for correction of *pectus excavatum* and by establishing a complete and integrated system of modelling, attainment of personalized geometry, and pre-operative modelling/bending appealing to specific equipment and software belonging to the owner.

Summary of the Invention

The present invention relates to a system of modelling/bending of surgical prosthesis used in the correction of *pectus excavatum*, allowing its pre-operative personalization according to the thoracic morphology of each patient. The system allows, on the basis of the information of the thoracic CT-scan, the application of a personalized prosthesis, reducing the initial discomfort provoked by the prosthesis and subsequent period of adaptation to the same, allowing still to reduce the duration of the surgery, and offering the patient a virtual perspective of the foreseen postoperative result.

For the effect, the system is constituted by:

- Simulation and modelling of surgical prosthesis, supported in software modules, developed specifically for the effect, being executed in a personal computer;
- Command and control of the machine, supported in software modules that are executed in a controller;
- An equipment that includes electronic and mechanical components, for the bending of personalized surgical prosthesis, to apply in the patient.

The software modules that are executed in the personal computer have a friendly interface with the user, mainly a set of menus that guide it step by step to reach the

intended goal - modelling the surgical prosthesis and simulation of the cosmetic result of its application in the patient. After the process of modelling and simulation, this application generates a set of points of control that will be sent to the controller. This includes software modules that allow receiving the control points sent by the application from the personal computer and based on this information commands and controls the equipment in an adaptive manner in the process of bending of surgical prosthesis.

Brief description of the drawings

Many of the aspects of the invention can be better understood regarding some drawings on the same. The components in the drawings are not necessarily to scale, emphasis is placed instead in the clear illustration of the principles of the present invention. The drawings are included with a non-limitative character, merely with the objective to provide a better understanding of the following description:

Figure 1: Represents a general three-dimensional perspective of an embodiment of the machine for the bending according to the invention.

Figure 2: Represents the general scheme of the different modules of the modelling/bending system.

Figure 3: Corresponds to a detailed bidimensional representation of the main body of the modelling/bending equipment.

Figure 4: Represents a detailed three-dimensional perspective of the head of the modelling equipment.

Figure 5: Represents a three-dimensional perspective of the equipment for modelling/bending of the surgical prosthesis.

Figure 6: Represents the general block diagram of the algorithm of the software application developed for the personal computer.

Detailed description of the invention

The present invention will now be described in detail, as a non-limitative example, by means of a preferred embodiment, represented in the enclosed drawings.

In reference to the figures, the preferred embodiment of the invention is described where the equipment is constituted by the following set of basic elements is described in detail: engines (1 and 2); main body of the machine (3); head of the machine (4); controller (9) and personal computer (8).

Electromechanical commands (see figures 1, 2 and 3) - the equipment has two engines (1 and 2). One of them (1) is connected to the main body of the machine (3) and undertakes the task of bending surgical prosthesis (6). The motor (2) is connected to the head of the machine (4) and its function is to execute the advance of the referred prosthesis.

Machine's main body (see figures 1, 3 and 4) - This is the part of the equipment where the great effort of bending is developed, necessary to the bending of surgical prosthesis(6). For the effect, the pivoting movement of the engine (1), is transformed into a translation movement, in the radial direction - axle z - to automatically adapt itself to the bending process requirements. That is obtained due to a system of ramp/piston (17 and 21).

The ramp (17), by a thread system (16), connected to the engine (1) through a universal joint (15), depending on the pivoting direction and speed received, assumes a two-way translation movement and actuates the piston (21), in the radial direction, axle z.

All the components of this mechanism, submitted to movements, are appropriately guided by bearing systems of rolling or slipping (18,19,20 and 25) and can be considered movements without friction or, if present, they can be ignored, in the scope of the efforts involved in the system. So being, high efforts, which are required in bending process of surgical prosthesis (6), are obtained.

It is still considered permissible the use of conventional mechanisms for this binomial of pivoting/translation movement such as: connecting rod/crankshaft; latch of moulds; screw/nuts and linear table; among others. There is further a system of springs (14) that guarantees the permanent contact between the piston (21) and the ramp (17).

For an efficient electronic control of the equipment, the existing movements in the machine's body (3) are in permanent contact with the controller (9), through electric sensors (5, 7, 12 and 13) here integrated. For the translation or drag movement of the surgical prosthesis (6) - axle x -, the main body of the equipment (3) holds two of the three shafts required to this movement (23 and 24), strategically placed such as to allow that surgical prosthesis (6) moves without the interfering with the static parts.

In this manner, the friction effect between the static parts of the body (3) and the head of the machine (4) with the surgical prosthesis (6) is prevented, when it is submitted to the translation movement. One of them (23) is connected to the advance motor (2) that for friction imposes the drag of the surgical prosthesis (6) - pivoting versus translation movement. The other shaft (24) is damped, which allows that when the piston (21) is retreated, the surgical prosthesis (6) is exclusively supported in the three lodes and is easily dragged by the motor (2).

On the other hand, the damping system of this shaft (24), allows a better static support of the surgical prosthesis (6) when this is submitted to the bending effort. The third shaft (28) is integrated in the head of the machine (4) and only serves as necessary support to the movement of translation of the surgical prosthesis (6).

The material of the surgical prosthesis (6) obeys the mechanical principles of the material, that identifies two deformation behaviours namely: tensile deformation and plastic or permanent deformation. The first one - tensile - refers to the deformation that is recovered and the second one - plastic - refers to the irrecoverable deformation, which means, to the deformation (or bending) definitively assumed, in a certain point, for the surgical prosthesis (6) after the retreat of the piston (21).

Herein resides another main objective of the present patent, that is if the material behaviour in mechanical processing is not previously recognized, nor would it be

possible - because, according to the state of the art, the material behaviour is intrinsically associated with a set of metallurgical and physical/mechanical parameters which are responsible for the fact that, in a same lot of the same hypothetical material, the mechanical behaviour is different, being therefore necessary that the system recognizes in each instant and in an adaptable way, the permanent deformation to which the surgical prosthesis (6) was submitted.

The materials used in the manufacture of this part of the equipment are compatible with the material to process - surgical prosthesis (6). To the main body of the machine (3) the motors (1 and 2) and the head of the machine (4) are also attached

Head of the machine (see figures 1,2 and 4) - the assignment given to this part of the equipment is enlightening as far as its functionality is concerned, that is, it is in this part that the bending of surgical prosthesis (6) is mechanically processed. Herein, the surgical prosthesis (6) is introduced in a channel (27), specifically opened for the effect, which by means of the motor movement (2), displaces the surgical prosthesis (6) in direction X (see figure 1), towards the position previously defined by the controller (9).

After the automatic positioning of the surgical prosthesis (6), the controller (9) makes the piston advance (21), through the motor (1), in the direction perpendicular to the surgical prosthesis axle (6) - axle z - which, in this way, bends the surgical prosthesis (6). For this effect a pin (26) attached to the head of the machine is provided,

that restricts the surgical prosthesis movement (6) in the direction of the axle z.

Likewise, and in the piston end (21), there is a pin (22), manufactured in a material that is compatible with the one surgical prosthesis (6) material, which facilitates its bending. The precision required for the bending is high. Such was obtained through the real time control of the behaviour of the material, which means, a displacement sensor (5) was integrated in the head of the machine (4) controlling in real time through a software application, specifically developed for the effect, the mechanical behaviour of the material referred to in the previous point. Therefore, it is possible to identify the tensile deformation parcels (recoverable) and permanent deformation parcels (of bending).

Such software application has is based on an algorithm that is divided into two parts. The first part of the algorithm is executed in the first bending point of the surgical prosthesis (6), and is characterized by the determination of the value corresponding to the plastic deformation of the material. This value is obtained through cycles of successive advances (incremental) and retreats (total) of the piston (21), towards to the surgical prosthesis (6). The stop condition of the cycle is given when displacement sensor (5) detects permanent deformation in the surgical prosthesis (6) at the moment that the piston is retreated. The second part of the algorithm is applied in each bending point of the surgical prosthesis (6), and is composed by two iterations. Each iteration consists of an advance movement and a retreat movement of the piston (21). For the first iteration the advance value of the piston (21) is

given by the addition of each bending point value to the plastic deformation value, previously calculated, to less than one constant (return factor - experimentally obtained). The use of a plastic deformation value inferior to the one calculated is related with the fact that the material obeys to a tension/deformation law that is not linear. For the second iteration, the advance value of the piston (21) is obtained in a weighed manner between the advance values of the first iteration and the required and effective bending values, after the retreat movement of the piston (21) in the first iteration.

The materials used in the production of this part of the equipment are compatible with the material to process.

Controller (see figure 2 and 5) - Figure 2 presents a general scheme of the different constituent blocks of the equipment, where a personal computer (8) emerges for an interface with the user (8). This allows the user to introduce the data that refers to the information of the thoracic CT-Scan (medical images) of the patient, and to get, through the software, a 3D representation of the profile and dimension of the surgical prosthesis (6), the localization and orientation to place the prosthesis in the intercostal space and perform a simulation of the cosmetic effect of the application of the prosthesis.

From the information obtained from the profile and dimension of the prosthesis virtually shaped, the developed software sends through the proprietor protocol a set of control points for the cited controller (9). This controller is responsible for the following set of functionalities: interpretation and translation of the control points sent by the personal computer (8);

synchronization and control of the axles xx and zz of the equipment; validation of the physical safety conditions of the same. For communication between the personal computer (8) and the controller (9) a communication protocol was implemented that has the protocol TCP/IP (Transfer Protocol Control/Internet Protocol) as its base, where a socket connection between the personal computer (8) and the controller (9) is established. In the last ones, an application layer was developed that defines a set of services such as the message format, the error correction code and the confirmation of a well-succeeded reception of the messages. These messages are of two types: status and data or information upload. The first gives information concerning the status of the two interlocutors (busy or free). The second sends information concerning the control points from the personal computer (8) to the controller (9). Thus, for example, when the user asks the computer's (8) resident software to actuate the bending of the surgical prosthesis (6), a message is sent to the controller (9) informing that the bending process is about to start. The controller (9) might answer in two ways: that it is free to start the process or that it is busy. In the first case, the personal computer's resident software (8) starts the data transmission to the controller (9) (control points); in the second case, the software sends a message to the user, informing that the controller (9) is busy and asks him to retry later. The use of this protocol allows the remote operation of the equipment, allowing its use via Web.

The equipment axles - movement/deformation directions of the surgical prosthesis (6) - are controlled in two different ways. The xx axle is constituted by the motor (2)

that provides it with movement and whose lode is connected to an "encoder" (7). The later is connected to the fast inlets of the controller (9). The motor (2) is actuated by a power driver (10) that is commanded by the controller (9), through a letter of digital outlets, thus closing in the control cycle. The movement through the zz axle is established by a motor (1) that provides it with movement and a displacement sensor (5). The later is connected to the controller (9) through analogical border entrances allowing the reading of the effective deformation of the surgical prosthesis (6) in the bending process. The motor (1) is set in motion through a power driver (11), which is commanded through the controller (9), by means of a letter of digital outlets. The control cycle herein implemented confers to the system a quality control of the bent prosthesis.

To assure the safety of the elements of the machine, the zz axle is protected by two movement sensors (12 and 13), that function as limits of end of course, the sensor (13) also functioning as an initial position sensor. These sensors (12, 13) are connected to the controller (9), by means of a letter of digital inlets.

The detection of the prosthesis by the equipment is given by the reading of the sensor (5), and the adjustment of the same for the initial position is made automatically, using for such a control mesh made by the motor (2), the controller (9) and closed by the sensor (5).

Personal computer (see figure 2 and 6) - the interface between the equipment and the user is made through a

software application that runs in a personal computer (8). This has a pleasant interface comprising a set of menus that guide the user step by step to reach the intended objective.

In this software application several 2D and 3D image processing techniques were used, of which the following two are outlined: 2D segmentation, that allows separating different structures based on colour differences at the points that are part of thoracic CT-Scan images; 3D segmentation, that allows separating different structures based on the spatial position of the points that are part of the image and in the identification of anatomo-surgical references - coronal plane and mid-axilla line. Within this scope, the software application allows the graphical 3D pre-operative simulation of the expected cosmetic result of the thoracic wall after placement of the surgical prosthesis (6) in the patient. In the pre-operative stage the points that represent the skin structure are used to reconstruct the three-dimensional model of the thoracic wall. This model is represented as surfaces with normal orientation. Features such as the bar placement point (obtained from the point of largest deflection of the sternum), correction factor of sternum (obtained from the most anterior point of ribs in the limit area) and stabilization factor of the sternum (corresponding to the displacement of the sternum after removal of the bar) are used to recalculate the position of each point associated to the surfaces that represent the skin affected by the correction of the malformation. The skin points directly associated to the spatial position of the sternum are directly affected by the correction factor of the sternum.

The neighbour points, herein referred as neighbour pectus, are affected by a matricial Gaussian distribution.

This application software has the following set of features:

- Reading of neutral files universally used in medical imagiology such as those resulting from CT-Scan and magnetic resonance systems;
- Identification, based on 2D image processing techniques, of the relevant points corresponding to the bone structure and the ones representing skin structure;
- Conversion of 2D images in 3D images based on conventional image processing techniques;
- Identification, based on 3D image processing techniques implemented through proprietary algorithms, of the following four structures: points corresponding to the ribs, posterior to the coronal plane that includes the mid-axilla line; points corresponding to the right ribs anterior to the coronal plane that includes the mid-axilla line; points corresponding to the left ribs anterior to the coronal plane that includes the mid-axilla line; points corresponding to the sternum;
- automatic detection of the point of largest deflection of the sternum;
- definition of the intercostal space; sternum points; right and left ribs interior to the limit box, with the lower base sitting on the plane that corresponds to the point of largest deflection of the sternum, and with the top base sitting on a plane parallel to the anterior plane and at a distance equal to the width of the surgical prosthesis (6);

- automatic correction of the sternum elevation to a predicted position, given by the correction factor of the sternum;
- possibility for the user to easily change, manually, the predicted position of the sternum;
- selection of the most adequate surgical prosthesis (6) to apply in the patient from standard sizes, based on the position defined for the sternum;
- positioning and visualizing the virtual surgical prosthesis modelled from the information previously determined: point of largest deflection and final position of the sternum,
- 3D visualization/simulation of the possible result to obtain with the placement of the surgical prosthesis (6);
- Automatic generation/selection of the control points to send to the controller (9) for subsequent bending of the surgical prosthesis (6);
- Sending of control points to the controller (9) using proprietary protocol.

The controller (9) and personal computer's (8) software applications were developed specifically for this modelling/bending system of surgical prosthesis used in the correction of *pectus excavatum*.

It must be clear that the automatic modelling/bending system of personalized surgical prosthesis (6) for correction of *pectus excavatum* based on pre-surgical imagiology information previously described is merely a possible implementation example established for a clear understanding of the principles of the invention. Variations and modifications can be made to the embodiment

previously described without substantially deviating from the spirit and principle of the invention. All these modifications and variations must be included in the subject of the scope of the present invention and be protected by the following claims.

CLAIMS

1. System for pre-surgical, automatic and personalized modelling/bending of surgical prosthesis (6) used in the correction of *pectus excavatum* **comprising** the following steps:

- recognizing patient data from medical imagiology systems in neutral format universally used;
- automatically creating a personalized virtual model of the surgical prosthesis (6) to apply in the patient, with interaction of the user and based on anatomo-surgical references clinically validated in the correction of *pectus excavatum*;
- simulating a pre-operative graphic of the expected cosmetic result of the thoracic wall after placing the surgical prosthesis (6) in the patient;
- sending of control points to a controller (9) through a proprietary communication software;
- initial and automatic insertion and positioning of the bar for the manufacture of the surgical prosthesis (6) in a bending machine, in the desired position so as to atrt the bending process;
- mechanical bending of the surgical prosthesis (6) by means of an automatic bending machine with real-time monitoring and control, being the prosthesis (6) already virtually generated and selected by the user.

2. System, according to claim 1, **characterized in that** the creation of the virtual model of the prosthesis includes the following steps:

- selecting and separating relevant points of the ribs, sternum and skin based on 2D image processing techniques;

- converting 2D images into 3D images based on conventional image processing techniques;
- segmenting from 3D images of the structures comprising the ribs and the sternum;
- automatically detecting the point of largest deflection of the sternum based on 3D coordinates of the points from the sternum;
- defining the limiting box where the intercostal space is inserted;
- automatic positioning of the sternum in a position predicted for the correction of *pectus excavatum*, based on the maximum point in the ribs belonging to the intercostal space - correction factor of the sternum, having this position the possibility of later manual modification by the user;
- virtual and personalized modelling of the surgical prosthesis (6) and selection of the most appropriate standard size to apply in the patient.

3. System, according to claim 2, **characterized in that** the segmentation from the 3D image of the rib structure and sternum structure comprises the following steps:

- identifying the coronal plane, that includes the mid-axilla line, that limits the anterior position to the ribs and consequently the initial and final point of the prosthesis (6);
- identifying the medial plane that, based on limits determined experimentally on the left and on the right of the respective plane, allows the separation of the sternum from the ribs.

4. System, according to claim 2, **characterized in that** the definition of the limit box where the intercostal space is located comprises the following steps:

- defining a plane, that includes the point of largest deflection of the sternum and is perpendicular to the sternum;
- creating a cuboid with one of the bases abutting on the defined plane and having a height equal to the width of the prosthesis (6);
- defining the required intercostals space through the points of the ribs interior to the cuboid.

5. System, according to claims 1 and 2, **characterized in that** the graphical pre-surgical simulation of the expected cosmetic result of the thoracic wall, after placement of the surgical prosthesis (6) in the patient, is obtained from information on the point of bar placement obtained from the point of largest deflection of the sternum, the correction factor of the sternum given by the most anterior point of the ribs present in the limit box and by the stabilizing factor of the sternum that corresponds to the displacement of the sternum after removing the bar.

6. System, according to claim 1, **characterized in that** the control of the process of initial positioning and bending is performed using a controller (9) that performs the data acquisition and processing of signals from the displacement sensors (12, 13) and which performs the control of motors for positioning (2) and bending (1), generating impulses for the respective power drivers (10, 11) based on information received by the displacement sensors (12, 13) and control points previously received through proprietary protocol.

7. System, according to claim 6, **characterized in that** the acquisition and processing of electric signals by the controller (9) follows an algorithm divided into two parts:

- the first part, at the first bending point, the plastic deformation value of the material is obtained through successive cycles of incremental loading/unloading until detection, by the displacement sensor (5), of permanent deflection in the surgical prosthesis (6) at the moment the piston (21) is in lower position;

- the second part, is applied at each bending point of the surgical prosthesis (6), and is composed by two iterations; in which in the first iteration the value of displacement of the piston (21) is given by the sum of the value of each bending point to the value of plastic deformation, previously calculated, at less than a reversal constant; in the second iteration, the value of displacement of the piston (21) is obtained considering the displacement value of the first iteration and the desired bending value.

8. System, according to claim 1, **characterized in that** the automatic bending machine of the surgical prosthesis (6) is composed by the following essential elements:

- electromechanical components including a first motor (1) connected to the main body of the machine (3) that promotes the bending of the surgical prosthesis (6) and a second motor (2) connected to the head of the machine (4) that promotes the pushing movement of the said prosthesis (6);
- a main body of the machine (3), that encloses two shafts (23, 24), necessary to guide the movement of the prosthesis (6) in which the pivoting movement from the motor (1) is transformed in translation movement to promote the bending process;

- a head of the machine (4), coupled to the main body of the machine (3), that contains a channel (27) where the surgical prosthesis is placed, a third support shaft (28) for assisting translation movement, in which the motor (2) promotes the movement process of the surgical prosthesis (6) to a position previously defined by the controller (9);
- a controller (9) that controls motors (1) and (2);
- a personal computer (8) that sends the control points to the controller (9) by means of a software application.

9. System, according to claim 8, **characterized in that** one of the three shafts (23, 24 and 28) of the positioning mechanism of the surgical prosthesis (6) is damped, through mechanical means such as springs, hydraulics pneumatic or others that during the bending stage promotes the support of the surgical prosthesis (6) in the head of the equipment and the bending of the said prosthesis, and releases the three shafts (23, 24 and 28) from the large bending loads imposed to the surgical prosthesis (6) during the bending process.

10. System, according to claim 8, **characterized in that** the bending of the prosthesis (6) is performed through mechanical, hydraulic, pneumatic or other means, that impose a bending load on the prosthesis (6), fixed at a predefined distance, causing a bending stress that, overcoming the yield stress of the material, permanently deforms the prosthesis (6).

11. System, according to claim 9, **characterized in that** the bending load for the bending process of the surgical prosthesis (6) is applied through a mechanical system composed of a motor (1), a ramp (17) and a piston (21) the

later having one a translational movement, perpendicular to the axis of the prosthesis (6), obtained by the transformation of the pivoting movement of the motor (1) / spindle (16) in translational movement of the ramp (17) that actuates the said piston (21).

12. System, according to claim 8, **characterized in that** the surgical prosthesis (6) are manufactured in metal, polymeric or composite materials.

13. Use of a system for pre-surgical bending/modelling of a surgical prosthesis (6), according to claim 8, **characterized in that** the said system is applied in the correction of *pectus excavatum*.

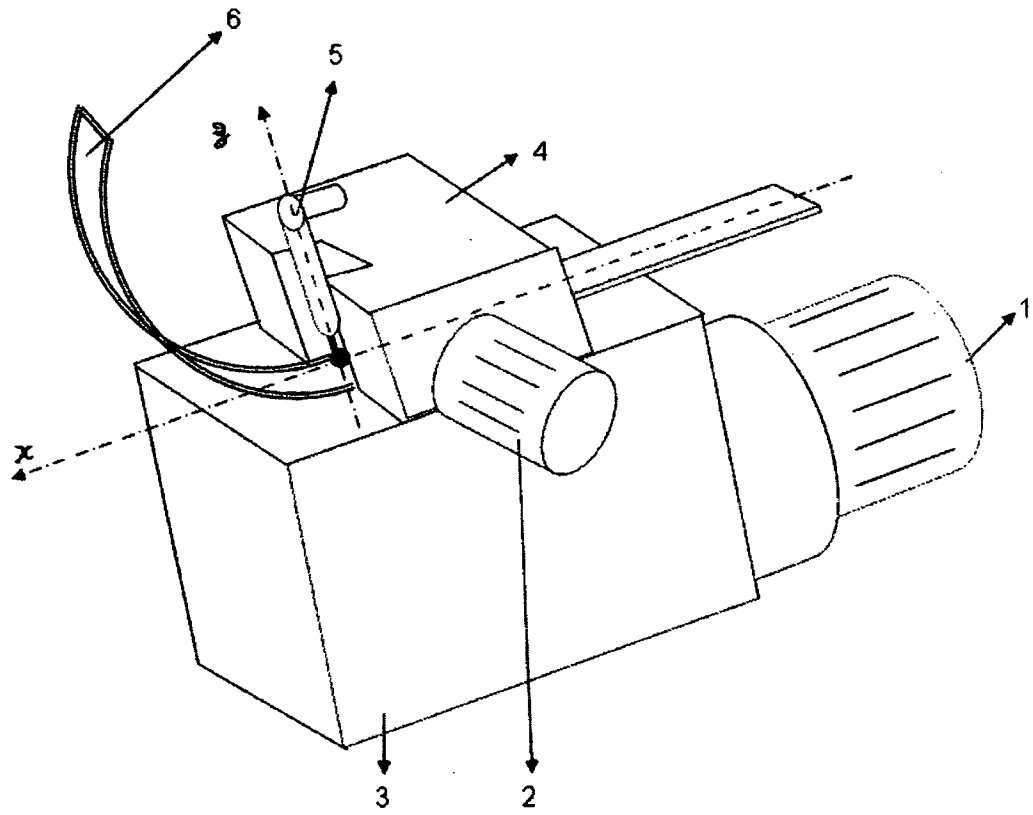


Fig. 1

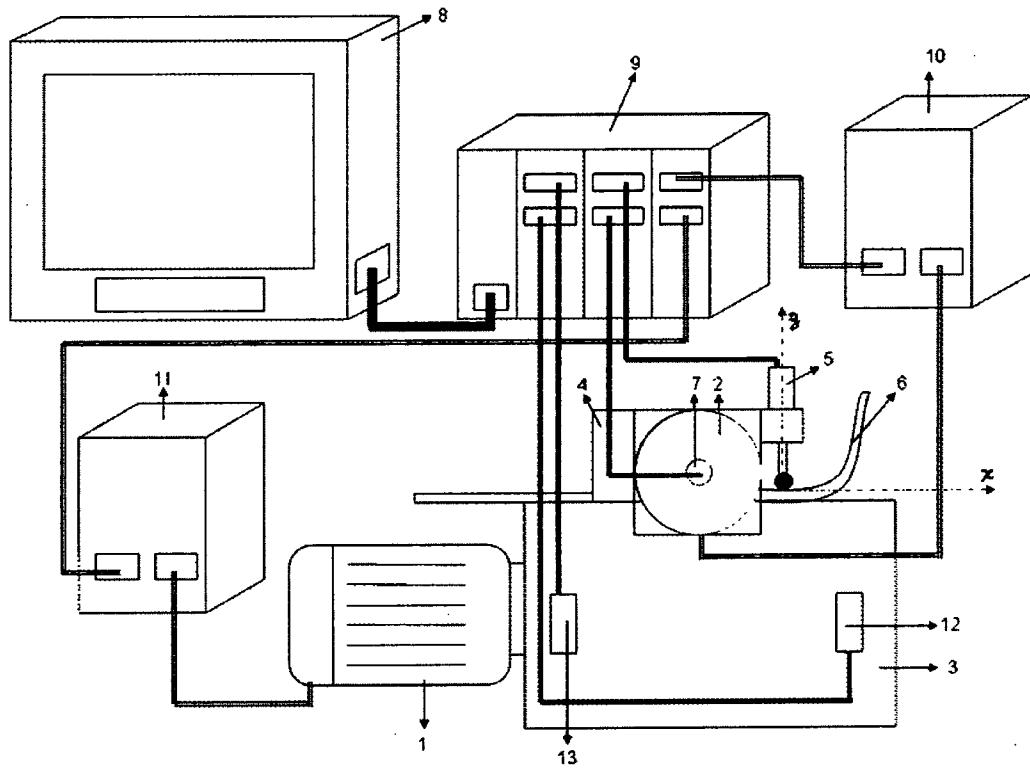


Fig. 2

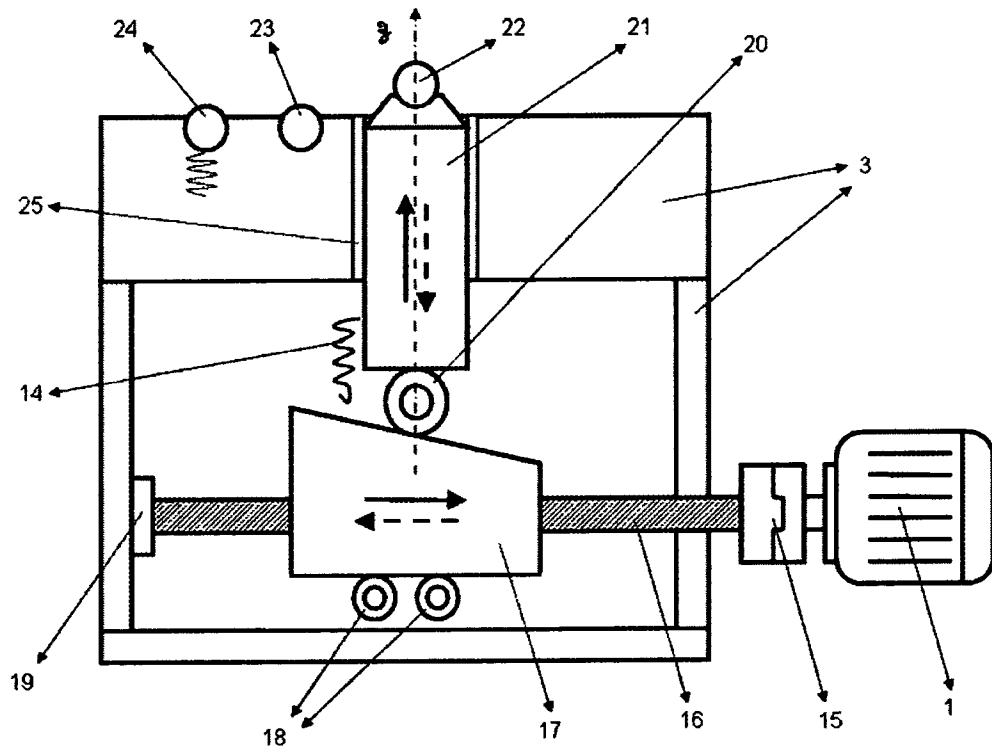


Fig. 3

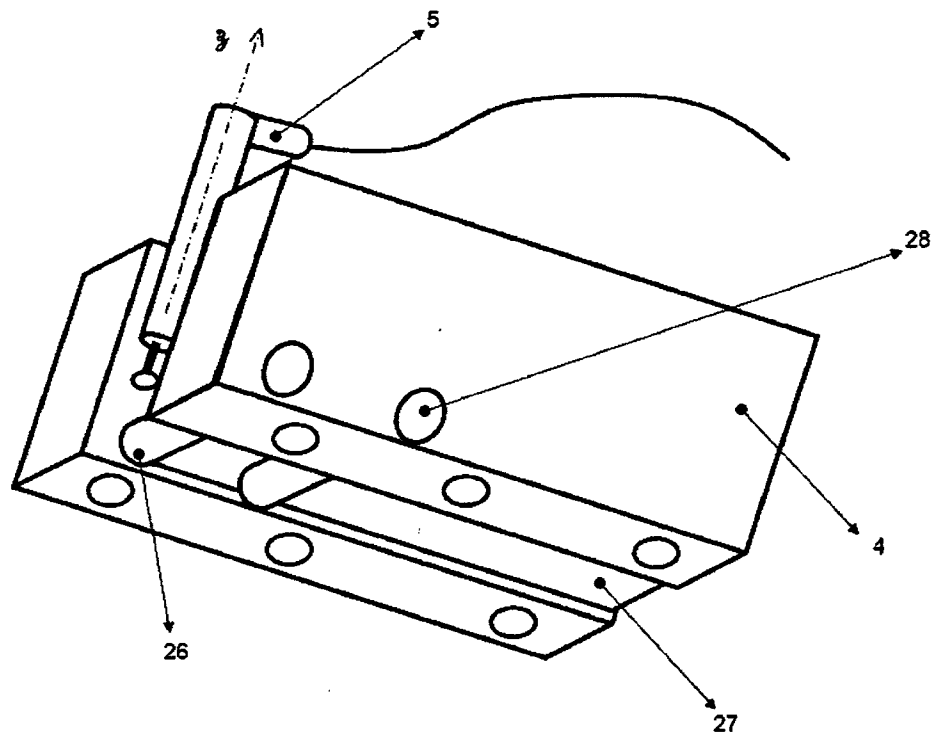


Fig. 4

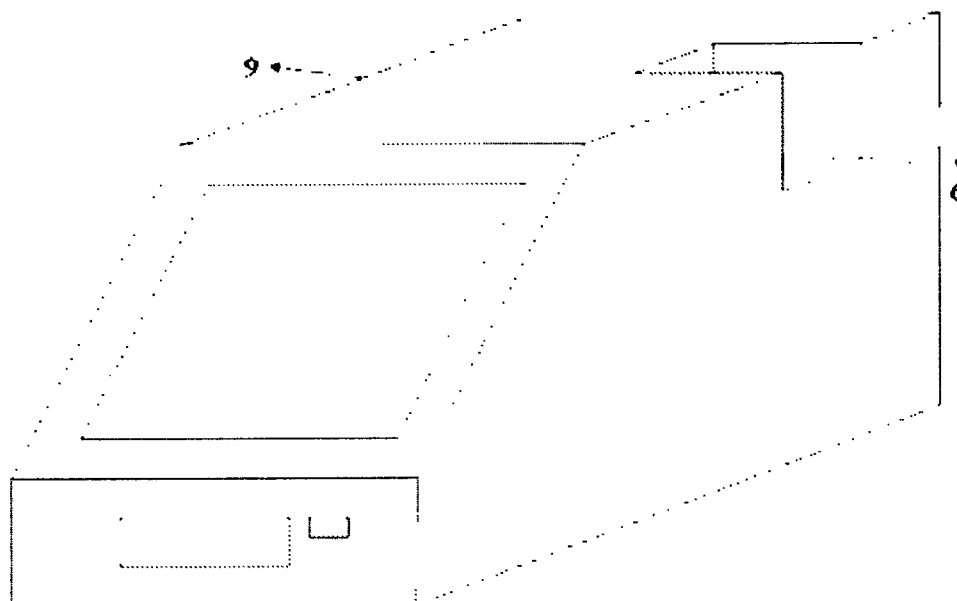


Fig. 5

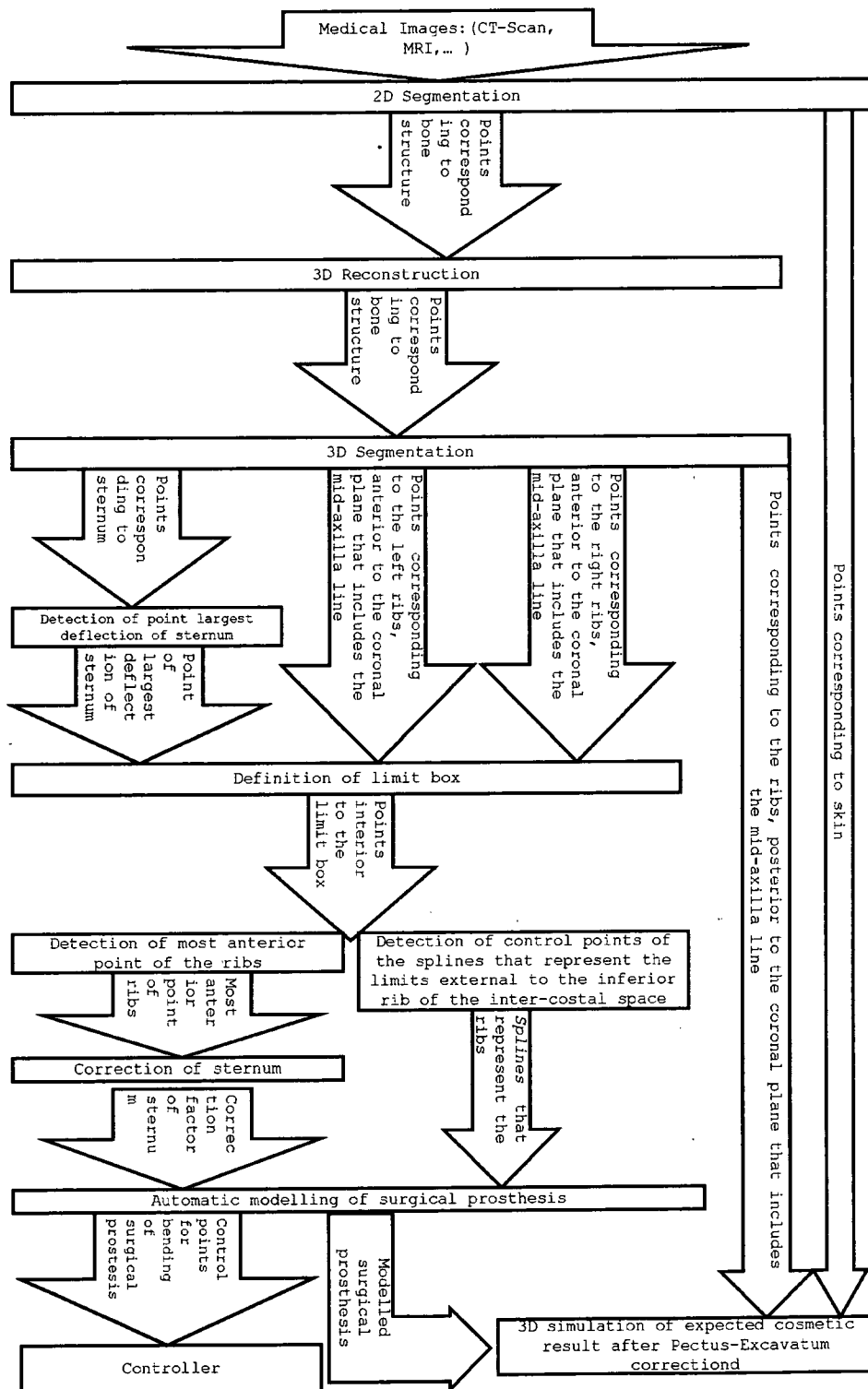


Fig. 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/PT2008/000016

A. CLASSIFICATION OF SUBJECT MATTER

INV. B21D11/00 A61F2/30 G06T7/00 G06T17/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

A61F A61B G05B A61C B21D G06T

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, BIOSIS, INSPEC, COMPENDEX

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2005/262911 A1 (DANKOWICZ HARRY [US] ET AL) 1 December 2005 (2005-12-01) the whole document	1
A	-----	2-5
Y	US 2004/243481 A1 (BRADBURY THOMAS J [US] ET AL) 2 December 2004 (2004-12-02) abstract; figure 2A page 4, paragraph 44 - page 8, paragraph 72 page 14, paragraph 130 - paragraph 135	1
A	----- -/--	2-5

☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

- *A* document defining the general state of the art which is not considered to be of particular relevance
- *E* earlier document but published on or after the international filing date
- *L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- *O* document referring to an oral disclosure, use, exhibition or other means
- *P* document published prior to the international filing date but later than the priority date claimed

- *T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- *X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- *Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
- * & * document member of the same patent family

Date of the actual completion of the international search

17 September 2008

Date of mailing of the international search report

27/01/2009

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Authorized officer

Salvador, Elena

INTERNATIONAL SEARCH REPORT

International application No

PCT/PT2008/000016

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	<p>FERRETTI G R ET AL: "Virtual tools for imaging of the thorax." THE EUROPEAN RESPIRATORY JOURNAL : OFFICIAL JOURNAL OF THE EUROPEAN SOCIETY FOR CLINICAL RESPIRATORY PHYSIOLOGY AUG 2001, vol. 18, no. 2, August 2001 (2001-08), pages 381-392, XP002495743 ISSN: 0903-1936 page 381 - page 383 Section "Chest wall" page 390; figure 7</p>	1-5
A	<p>PRETORIUS E S ET AL: "Spiral CT with 3D reconstruction in children requiring reoperation for failure of chest wall growth after pectus excavatum surgery. Preliminary observations." CLINICAL IMAGING 1998 MAR-APR, vol. 22, no. 2, March 1998 (1998-03), pages 108-116, XP002495744 ISSN: 0899-7071 the whole document</p>	1-5
A	<p>RUSHING ET AL: "When it is not an infection: metal allergy after the Nuss procedure for repair of pectus excavatum" JOURNAL OF PEDIATRIC SURGERY, W. B. SAUNDERS COMPANY, US, vol. 42, no. 1, 17 January 2007 (2007-01-17), pages 93-97, XP005821080 ISSN: 0022-3468 page 94, right-hand column, line 8 - line 19 page 96, left-hand column, line 25 - line 34</p>	1-5
A	<p>US 6 024 759 A (NUSS DONALD [US] ET AL) 15 February 2000 (2000-02-15) cited in the application the whole document</p>	1-5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/PT2008/000016

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers allsearchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search reportcovers only those claims for which fees were paid, specifically claims Nos.:
4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-5

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-5

System for pre-surgical, automatic and personalised
modelling of surgical prosthesis used in the correction of
pectus excavatum

2. claims: 6-13

System for automatic bending of surgical prosthesis used in
the correction of pectus excavatum

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/PT2008/000016

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2005262911	A1	01-12-2005	NONE
US 2004243481	A1	02-12-2004	NONE
US 6024759	A	15-02-2000	NONE