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(54) Title: KNEE ERGONOMIC DEVICE FOR RESOLVING THE VERTICAL LOADS

(57) Abstract: The device consists of a femoral support (1) and a tibial support (2) joined together by means of a lateral hinge and one or two medial hinges. Pins (1.5, 1.6, 1.7, 1.8) and openings (1.9, 1.10) present on the rounded distal end of each femoral arm (1.1, 1.2) and the openings (2.4, 2.5, 2.6) and pins (2.7, 2.8) present on the rounded proximal end of each tibial arm (2.1, 2.2) make up the lateral hinge and a proximal medial hinge. The medial tibial arm can be divided in two parts: a fixed medial tibial arm (2.12) connected to the tibial plate (2.11) and a free-moving medial tibial arm (2.13) secured to the fixed medial tibial arm (2.12) by means of a distal medial hinge. The pins (1.5, 1.6, 1.7, 1.8, 2.15, 2.17) are secured to plates (4, 5). The device can break down the load on mechanical components thus avoiding weight bearing on deficient structures as a result of pathologies or traumas.

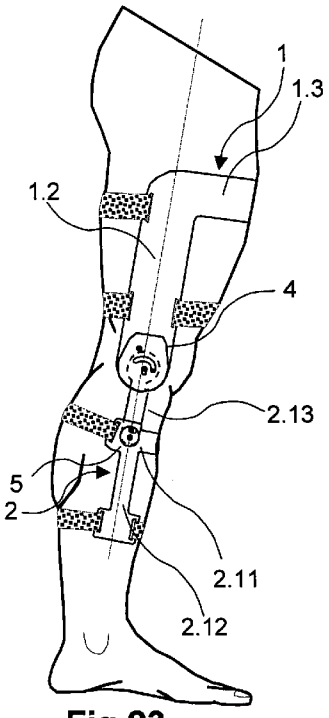


Fig.23

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Knee ergonomic device for resolving the vertical loads.

Field of the invention

The device can be used in the medical sector as a knee brace supporting the vertical loads which are axially transmitted on cartilages.

Background of the invention

The knee is the intermediate joint of the lower limb. Its degree of free range allows for a movement of flexo-extension.

The articular mechanics is complex and the type of movement performed is directly related to the opening angle of the knee. If we take the extended lower limb as a starting point, the leg carries out a motion of pure rotation over the first 25-30° of flexion. From that angle on, up to maximal flexion (around 135°), there is a double movement of rolling and gliding. More specifically, after an initial prevalence of rotation of the femoral condyles on the tibial tray, as the flexion movement proceeds, gliding becomes increasingly more progressive and predominant with respect to rolling. Such sliding motion of the joint is known as roto-traslatory.

Moreover, the different anatomical conformation of the lateral and medial compartments of the knee leads – during flexo-extension – to an automatic longitudinal rotation of the tibia vis-à-vis the femur, which is estimated at around 20 degrees by some authors.

Knee braces aim at containing the lateral movements of the knee after suffering a trauma.

Generally speaking, a common knee brace consists of a femoral support and a tibial support. The femoral support includes a lateral femoral arm and a medial femoral arm, which are secured to the thigh by means of straps, parallel to its longitudinal axis. The tibial support comprises a lateral tibial arm and a medial tibial arm, which are secured to the leg by means of straps, parallel to its longitudinal axis.

Each femoral arm is coupled with the respective tibial arm through a hinge at knee level which imposes its movement to the whole joint.

Looking at Figures 1 and 2, a more thorough analysis of the knee joint shows that, in the light of the rounded shape of the articular surfaces, there are only two contact points (covered with cartilage) in the joint: one is between the femoral condyle and the tibial tray in the medial compartment (point A), the other being between the femoral condyle and the tibial tray in the lateral compartment (point B).

A healthy knee, therefore, always preserves two contact points between the articular surfaces, their distances remaining perfectly constant.

When traumas and/or pathologies affect the proper functioning of an articular component, such as a ligament, a meniscus or a degenerated articular cartilage, the distance ratios between the articular surfaces are compromised and consequently prevent the entire knee from functioning properly. An injury to the cruciate ligaments does not allow for adequate control of the rolling and gliding movements of the femoral condyles on the tibial trays during flexo-extension. As a result, an anomalous friction of the articular surfaces takes place and the cartilages wear down.

All known devices impose their trajectory to the joint. If the trajectory does not coincide with the physiological one, a traditional device would drag the joint on its own trajectory thereby producing within the joint further tensions which are passed on to the organic structures already weakened by conditions and/or traumas.

This problem has been dealt with by various patents, including the application for European Patent No. 0 361 405, Patent No. WO 84/03433, Patent No. WO 92/15264 and Patent No. WO 97/38759. In particular, Patent No. WO 97/38759 describes a hinge characterized by a roto-traslatory motion. The hinge consists of two plates, which can freely rotate one on the other, each provided with a femoral arm and a tibial arm. The first plate has two openings, one placed centrally, the other peripherally. The central opening has a rectangular shape, with preferably rounded extremities. Its proximal extremity corresponds with a hole situated at the centre of the plate itself. The central

opening starts from this central hole and proceeds towards the periphery of the plate along the "a" axis which coincides with the symmetry axis of the tibial arm. An extremity of this second opening is situated on a "b" axis, perpendicular to the "a" axis at a distance "l" from the centre of the above-mentioned central hole. The other extremity of the second opening is placed at 130-140 degrees vis-à-vis the axis which originates the first extremity. The peripheral opening is specifically shaped: initially, in the first 25-30 degrees starting from the above-mentioned axis which generates the first extremity, it is a circumference whose centre coincides with the centre of the plate, its radius being equal to "l"; subsequently, in the remaining 105-110 degrees, it is a spiral heading back towards the centre of the plate. The sequence of points which make up the longitudinal axis of the spiral is obtained from the sequence of points of the extremity of a segment having an "l" length, whose second extremity moves along the longitudinal axis of the central opening, from the centre of the plate to the outside.

The second plate has two pins, placed at a distance equal to "l", each with its longitudinal axis orthogonal to the rotation surfaces of the plates. The first pin is situated in a central position on the second plate and slides in the central opening of the first plate. The second pin is situated in a peripheral position and slides in the peripheral opening. They are both through pins and are equipped with a distant constraint that prevents disjunction of the two plates. The axis of the central pin is defined as "c" axis and corresponds with the horizontal intercondylar axis around which the initial rotation of the knee develops.

The resulting hinge performs a roto-traslatory motion. If we assume the extended leg as a starting point, in the first 25-30 degrees the hinge carries out a purely rotatory movement imposed by the second pin which slides in the circular section of the peripheral opening, similarly to the rotation described by the knee in this arch-shaped movement. As flexion proceeds, the rotatory motion is accompanied – in an increasingly progressive way – by a sliding

motion of the second plate vis-à-vis the first one, when the second pin travels along the spiral-shaped part of the peripheral opening, similarly to what happens between the femoral condyles and the tibial trays in the 25-30° to 135° range.

The hinge described so far is functional for a theoretical knee. However, the length of the cruciate ligaments, their sizes and their insertion points – which characterize the articular surfaces – are different from one person to another. In order to study the true articular profile of a knee, it would be necessary to submit each individual to X-rays or to experimental measurements of the knee-malleolus distance; as a result, the spiral-shaped path followed by the hinge should be adjusted to that of the movement of the knee in each individual subject.

Patent No. WO 97/38759 does solve the problem of the typical roto-traslatory movement of the knee and is particularly indicated to restrain the knee laterally and antero-posteriorly in case of prevalently ligamentous deficiency. However, it does not take into account the longitudinal rotation of the tibia and the possibility of providing vertical support to the knee in case of traumas or degeneration of menisci and articular cartilages.

Summary of the invention

The object of the present invention is to provide a knee device capable of tracking all the movements performed by the knee during flexo-extension.

The device is also designed to break down the load determined by the bodyweight on various mechanical organs, parallel to the knee itself, so as to prevent the load itself from bearing on organic structures weakened by pathological and/or traumatic causes.

The device consists of a femoral support and a tibial support.

The femoral support comprises a lateral femoral arm and a medial femoral arm, parallel to one another and to the longitudinal axis of the thigh. They are joined together by means of a rigid or semirigid arch-shaped plate and straps passing through linear openings situated on the femoral arms. The femoral

arms could also be joined together by straps alone.

The tibial support consists of a lateral tibial arm and a medial tibial arm, parallel to one another and to the longitudinal axis of the leg. They are joined together by means of straps which pass through linear openings situated on the tibial arms. The tibial arms could also be joined together by means of an arch-shaped plate and the afore-mentioned straps. Such tibial plate could also be secured to each tibial arm by a fastener.

The distal ends of the femoral arms and the proximal ends of the tibial arms are articulated to each other by means of at least two hinges, one placed laterally and the other medially to the knee. The distal ends of each femoral arm and the proximal ends of each tibial arm – which make up the hinge – are shaped as rounded plates.

The rounded distal end of each femoral arm accommodates four screwed pins and two openings. The first pin is placed centrally on the distal end along the "a" axis which coincides with the axis of longitudinal symmetry of the femoral arm itself. The second pin is placed peripherally on the end of the femoral arm, at a distance "l" with respect to the central pin, along a "b" axis perpendicular to the "a" axis. The axes "a" and "b" ideally divide the distal end of the femoral arm into four quadrants: the first one oriented towards the foot and the posterior part of the leg; the second one oriented towards the foot and the anterior part of the leg; the third one oriented towards the root of the lower limb and the posterior part of the leg; the fourth one oriented towards the root of the lower limb and the anterior part of the leg.

The third pin is placed proximally with respect to the afore-mentioned pins, in the quadrant oriented towards the root of the lower limb and the posterior part of the leg. It is situated at a distance "r" with respect to the central pin. The "d" axis which passes through the centre of the proximal pin and the centre of the central pin deviates by a few degrees from the "a" axis. The peripheral edge of the third pin is tangential to the "a" axis itself.

The "d" axis continues towards the peripheral distal edge of the femoral arm.

Along such axis – at a distance "r" from the central pin –is situated the fourth pin, diametrically opposed to the proximal pin vis-à-vis the central pin. The peripheral edge of the distal pin too is tangential to the "a" axis. The distal pin is situated in the quadrant oriented towards the foot and the anterior part of the leg.

The first opening is located near the peripheral edge of the rounded distal end of the femoral arm and is extended in the two quadrants oriented towards the posterior part of the leg. At the origin of this first opening, one of its extremities is situated at a distance "r" from the central pin along the "d1" axis which is perfectly symmetrical to the "d" axis vis-à-vis the "a" axis. The edge of the first extremity of the first opening is tangential to the "a" axis and to the peripheral edge of the distal pin. The first opening, after describing an initial arc of circumference, turns into a spiral which gets near the rounded distal end of the femoral arm.

The second opening, diametrically opposed to the first one with respect to the "a" axis, is located in the two quadrants oriented towards the anterior part of the leg. At the origin of this second opening, one of its extremities is situated at a distance "r" from the central pin and deviates by a few degrees from the longitudinal axis "a" of the femoral arm. The edge of the first extremity of the second opening is tangential to the "a" axis and to the peripheral edge of the proximal pin. The second opening, after describing an initial arc of circumference, turns into a spiral which - contrary to the first opening - gets away from the centre of the rounded distal end of the femoral arm.

The proximal end of each tibial arm is provided with three openings and two pins. The first tibial opening has a rectangular shape and rounded extremities. Its proximal extremity is obtained by creating a hole at the centre of the proximal extremity of each tibial arm and then proceeding towards the foot along the "a1" axis of longitudinal symmetry of the tibial arm.

The second opening is located peripherally on the proximal end of each tibial arm and is extended for 130°-140°. The first extremity of this peripheral

opening is situated on a "b1" axis, perpendicular to the "a1" axis, at a distance "l" from the centre of the above-mentioned central hole from which the first opening originates. The other extremity of the second tibial opening is placed at 130-140° with respect to the axis which originates the first extremity. The peripheral opening, after describing an initial circumference whose centre coincides with that of the proximal extremity of the central opening and whose radius is equal to "l", turns into a spiral which returns towards the centre of the plate.

The "a1" and "b1" axes ideally divide the proximal end of each tibial arm into four quadrants; the first one is oriented towards the foot and the posterior part of the leg; the second one is oriented towards the foot and the anterior part of the leg; the third one is oriented towards the root of the lower limb and the posterior part of the leg; the fourth one is oriented towards the root of the lower limb and the anterior part of the leg. The central opening is placed in the two quadrants oriented towards the foot, the second tibial opening is placed in the two quadrants oriented towards the root of the lower limb.

The third tibial opening, which is extended for 130°-140°, has a first semicircular extremity that is placed at a distance "r" from the intersection of the "a1" and "b1" axes in the quadrant oriented towards the foot and the anterior part of the leg, and deviates by a few degrees from the "a1" axis. The edge of the extremity of the third tibial opening is tangential to the "a1" axis. The third tibial opening, after describing an initial arc of circumference, turns into a spiral which gets near the rounded proximal end of the tibial arm.

The first tibial pin is situated distally vis-à-vis the central opening, at a distance "r" from the intersection of the "a1", "b1" axes, in the quadrant oriented towards the foot and the posterior part of the leg. The "d2" axis which passes through the centre of the pin and the intersection of the "a1", "b1" axes deviates by a few degrees from the "a1" axis. Its peripheral edge is tangential to the "a1" axis itself and to the first extremity of the second peripheral tibial opening.

The second tibial pin is diametrically opposed to the first tibial pin with respect to the "a1" axis; consequently the axis which passes through the centre of the pin itself and the intersection of the "a1" and "b1" axes deviates by a few degrees from the "a1" axis, though in the opposite direction. The peripheral edge of the second tibial pin too is tangential to the "a1" axis. The second tibial pin is placed in the quadrant oriented towards the root of the lower limb and the anterior part of the leg.

The peripheral edge of the end of the tibial arm is extended in the quadrants oriented towards the posterior part of the leg and is shaped in such a particular way that its initial section – extending in the posterior quadrant oriented towards the root of the limb – describes a circumference arc. The successive section of the peripheral edge – extending in the posterior quadrant oriented towards the foot – is shaped as a spiral that tends to get away from the centre of the plate. The peripheral surface of the proximal pin of the femoral arm remains in constant contact with the peripheral edge of the tibial arm during the roto-traslatory movement of the latter vis-à-vis the femoral arm.

The longitudinal axis of the central pin of the lateral hinge and the longitudinal axis of the central pin of the medial hinge are coaxial. Such axis coincides with the "c" axis which passes through the femoral condyles and around which the phase of initial rotation of the knee takes place.

The medial tibial arm can be divided in two parts: a fixed medial tibial arm (fastened to a tibial plate) and a free-moving medial tibial arm which pivots on the fixed arm itself by means of a second medial hinge. The tibial plate is arc-shaped, is made of rigid material with a good harmonic response and tracks the anterior part of the leg. The mobile medial tibial arm consists of a rectilinear plate extending between the medial femoral arm and the fixed medial tibial arm. The medial femoral arm of the femoral support is secured to the proximal end of the free-moving medial tibial arm by means of the above-mentioned medial hinge. The distal end of the mobile medial arm is provided

with a hole (situated along the symmetry axis of the mobile arm itself), engaged by a pin placed at the intersection between the symmetry axis of the tibial plate and the symmetry axis of the fixed medial tibial arm. An arc-shaped opening is located along the symmetry axis of the mobile medial tibial arm, in a proximal position with respect to the hole. Such opening accommodates a second pin, which is secured to the fixed medial tibial arm and is situated proximally vis-à-vis the pin along the symmetry axis of the fixed medial tibial arm itself. These elements form a second medial hinge.

More arc-shaped openings and more holes can be made on the distal end of the free-moving medial tibial arm along its symmetry axis. The centre of a semicircular extremity of the openings is placed along the same symmetry axis.

The lateral tibial arm too can be divided into a proximal lateral tibial arm and a distal lateral tibial arm. The proximal lateral tibial arm has an elongated shape and the distal lateral tibial arm is fastened to the tibial plate. At least three equidistant holes are made on the prolongation of the proximal lateral tibial arm and along its symmetry axis. The distal lateral tibial arm accommodates at least two threaded holes, coaxial to at least two holes present on the proximal lateral tibial arm. Two screws pass through the holes of the proximal lateral tibial arm and are secured to two threaded holes of the distal lateral tibial arm.

The pins of the distal ends of the femoral arms and of the fixed medial tibial arm are secured to a plate external to each hinge by means of fasteners. In each plate there are holes placed coaxially with the pins of the femoral arms and of the fixed medial tibial arm. It is through such holes of each plate that the free ends of the pins themselves or the afore-mentioned fasteners engaged to the pins do pass, thereby securing each plate to each femoral arm and to the fixed medial tibial arm, and preventing their disjunction. The fasteners could be screws for engaging the threaded holes of the pins or rivets with their free end engaging in the holes of the pins or nuts that engage

the external thread of the pins. The height of the pins is greater than the thickness of the tibial arm.

The present device is capable – even in weight-bearing conditions – of keeping the articulation surfaces well spaced, though submitted to the weight of the body that tends to compress them on one another.

The knee support, while tracking the knee in its motion of antero-posterior flexo-extension, at the same time prevents the lateral and antero-posterior movements of the knee determined by deficient articular structures following a trauma.

The device allows the knee to carry out an ergonomic movement which adequately tracks the physiological one, particularly in the light of the longitudinal automatic rotation of the tibia, contrary to the movement imposed by the best known devices.

Brief description of the drawings

Further features of the present invention will emerge from the description of an embodiment, preferable but not exclusive, of the device, illustrated in the attached drawings by way of example and not limitation:

- Figure 1 is a front elevation view of a lower limb;
- Figure 2 is an elevation view from above of the tibial trays along the transversal plane of the knee, showing the points of contact with the femoral condyles and the "c" axis;
- Figure 3 is a front elevation view of the knee;
- Figure 4 is an elevation view from above of the tibial trays along the transversal plane of the knee, showing the points of contact with the femoral condyles;
- Figure 5 shows the lower limb in extended position with the indication of the longitudinal axis, transversal axis and front plane;
- Figure 6 is an elevation view from above of the skeletal portion of the knee, showing the points of contact between the articulation surfaces of the knee and the front elevation view;

- Figure 7 shows the lower limb in flexed position with the indication of the front plane of the thigh and the front plane of the leg;
- Figure 8 is an elevation view from above of the skeletal portion of the knee flexed at 90 degrees, showing the contact points between the articulation surfaces of the knee, the front elevation view of the leg and the front elevation view of the thigh;
- Figure 9 is a lateral elevation view of a first preferred embodiment of the present invention, secured to the wearer's limb from a medial perspective;
- Figure 10 is a front elevation view of the device shown in Figure 9, secured to the wearer's limb viewed frontally;
- Figure 11 is a lateral elevation view of a femoral arm of the device;
- Figure 12 is a lateral elevation view of a tibial arm of the device;
- Figure 13 is a lateral elevation view of the same femoral arm shown in Figure 11 with some schematic representations of construction;
- Figure 14 is a lateral elevation view of the same tibial arm shown in Figure 12 with some schematic representations of construction;
- Figures 15, 16, 17 and 18 show the movements of a hinge of the device;
- Figure 19 shows the distribution of load on the leg when using the present device;
- Figure 20 is a perspective view of the femoral support of the device in a second preferred embodiment;
- Figure 21 is a perspective view of the free-moving medial arm of the device in a second preferred embodiment;
- Figure 22 is a perspective view of the tibial support of the device in a second preferred embodiment;
- Figure 23 is a lateral elevation view of the device in a second preferred embodiment, secured to the wearer's limb viewed medially;
- Figure 24 is a lateral elevation view of the device in a second preferred embodiment, secured to the wearer's limb viewed laterally;
- Figure 25 is a front elevation view of the device in a second preferred

embodiment, secured to the wearer's limb viewed frontally;

- Figure 26 is a front elevation view of the free-moving tibial arm;

- Figure 27 shows the device in a second preferred embodiment, without the covering plates, in a position corresponding to that adopted when secured to the leg in the extended position;

- Figure 28 shows the same device, without the covering plates, in a position corresponding to that adopted when secured to the leg on a 15-degree flexion;

- Figure 29 shows the same device, without the covering plates, in a position corresponding to that adopted when secured to the leg on a 35-degree flexion;

- Figure 30 shows the same device, without the covering plates, in a position corresponding to that adopted when secured to the leg flexed above 90 degrees;

- Figure 31 is a front elevation view of a modified free-moving tibial arm;

- Figure 32 is a lateral elevation view of a modified proximal lateral tibial arm, separated from the distal lateral tibial arm;

- Figure 33 is a lateral elevation view of a modified distal lateral tibial arm;

- Figure 34 shows the distribution of forces on a hinge in case of chondropathy;

- Figure 35 shows the distribution of forces on a hinge in case of injury or trauma to the posterior cruciate ligament.

Detailed description of two preferred embodiments

As shown in Figures 3 to 8, the first preferred embodiment of the present invention consists of a femoral support 1 and a tibial support 2.

The femoral support 1 comprises a lateral femoral arm 1.1 and a medial femoral arm 1.2, which are parallel to each other and to the longitudinal axis of the thigh and are joined together by means of an arch-shaped rigid or semirigid plate 1.3 and by straps 3.

The inner surface of the femoral plate 1.3 tracks the anterior part of the leg.

Linear openings 1.4 are present on each femoral arm 1.1, 1.2. The straps 3, which have a face made of nylon Velcro®, pass through such linear openings 1.4. The straps are wrapped all around the thigh anteriorly and posteriorly, thus securing the femoral support 1.1 to the thigh, together with the plate 1.3.

The tibial support 2 consists of a lateral tibial arm 2.1 and a medial tibial arm 2.2, which are parallel to each other and to the longitudinal axis of the leg. Linear openings 2.3 are present on the tibial arms 2.1, 2.2 too. The straps 3, which have a face made of nylon Velcro®, pass through such linear openings 2.3, and are wrapped all around the leg, thus securing the tibial support 2 to the leg itself.

The distal ends of the femoral arms 1.1, 1.2 and the proximal ends of the tibial arms 2.1, 2.2 are joined together by means of two hinges, one placed laterally with respect to the knee, the other placed medially. The distal ends of each femoral arm 1.1, 1.2 and the proximal ends of the each tibial arm 2.1, 2.2, which make up the hinge, are shaped as plates and are rounded.

For clarity purposes, let us consider only the hinge present in the medial compartment of the knee: four pins 1.5, 1.6, 1.7, 1.8 are fixed on the rounded distal end of the medial femoral arm 1.2; two openings 1.9, 1.10 are also present on the same end of the medial femoral arm 1.2.

A first pin 1.5 is located on the distal end of the medial femoral arm 1.2 and is placed centrally along the "a" axis which coincides with the axis of longitudinal symmetry of the medial femoral arm 1.2 itself.

A second pin 1.6 is located on the distal end of the medial femoral arm 1.2 and is placed peripherally at a distance "l" with respect to the central pin 1.5, along the "b" axis, perpendicular to the "a" axis.

The axes "a" and "b" ideally divide the distal end of the medial femoral arm 1.2 into four quadrants: the first one oriented towards the foot and the posterior part of the leg; the second one oriented towards the foot and the anterior part of the leg; the third one oriented towards the root of the lower limb and the posterior part of the leg; the fourth one oriented towards the root

of the lower limb and the anterior part of the leg.

The third pin 1.7 is placed proximally with respect to the afore-mentioned pins 1.5, 1.6, in the quadrant oriented towards the root of the lower limb and the posterior part of the leg. It is situated at a distance "r" with respect to the central pin 1.5. The "d" axis which passes through the centre of the proximal pin 1.7 and the centre of the central pin 1.5 deviates by a few degrees from the "a" axis. The peripheral edge of the proximal pin 1.7 is tangential to the "a" axis itself.

The "d" axis, which passes through the centre of the proximal pin 1.7 and the centre of the central pin 1.5, continues its path towards the peripheral distal edge of the medial femoral arm 1.2. Along such axis – at a distance "r" from the central pin 1.5 – there is a fourth pin 1.8, diametrically opposed to the pin 1.7 vis-à-vis the central pin 1.5. The peripheral edge of the distal pin 1.8 too is tangential to the "a" axis. The distal pin 1.8 is situated in the quadrant oriented towards the foot and the anterior part of the leg.

The first opening 1.9 is located near the peripheral edge of the rounded distal end of the medial femoral arm 1.2 and is extended in the two quadrants oriented towards the posterior part of the leg for 130-140 degrees. The centre of a first semicircular extremity of the opening 1.9 is situated at a distance "r" from the central pin 1.5 along a "d1" axis which is perfectly symmetrical to the "d" axis vis-à-vis the "a" axis. The edge of the first semicircular extremity of the opening 1.9 is tangential to the "a" axis and to the peripheral edge of the distal pin 1.8. The opening 1.9 has a particular shape: over the first 25-30 degrees starting from the first extremity, it describes an arc of circumference; from 25-30 degrees on, up to 130-140 degrees, it turns into a spiral which gets near the rounded distal end of the medial femoral arm 1.2. More specifically, the points that make up the longitudinal axis of this spiral are situated at an increasingly lower distance from the centre of the rounded distal end of the medial femoral arm 1.2 as they get closer to the second extremity, which is semicircular too.

The second opening 1.10, diametrically opposed to the opening 1.9 with respect to the "a" axis, is located in the two quadrants oriented towards the anterior part of the leg. The centre of a first semicircular extremity of the opening 1.10 is situated at a distance "r" from the central pin 1.5 along the "d1" axis. The edge of the first semicircular extremity of the opening 1.10 is tangential to the "a" axis and to the peripheral edge of the proximal pin 1.7. The opening 1.10 too describes an arc of circumference over the first 25-30 degrees starting from the first extremity. Yet - contrary to the opening 1.9 – from 25-30 degrees on, up to 130-140 degrees, it turns into a spiral which gets away from the centre of the rounded distal end of the medial femoral arm 1.2. More specifically, the points that make up the longitudinal axis of this spiral are situated at an increasingly greater distance from the centre of the rounded distal end as they get closer to the second extremity.

The plate located at the proximal end of the medial tibial arm 2.2 is provided with three openings 2.4, 2.5, 2.6 and two pins 2.7, 2.8.

The first tibial opening 2.4 has a rectangular shape and rounded extremities. The first tibial opening 2.4 is obtained by creating a hole at the centre of the plate of the proximal end of the medial tibial arm 2.2 and then proceeding towards the foot along the "a1" axis of longitudinal symmetry of the medial tibial arm 2.2. The hole is the proximal extremity of the first tibial opening 2.4.

The second opening 2.5 is located peripherally on the proximal end of the medial tibial arm 2.2 and is extended for 130°-140°. The first extremity of this second opening 2.5 is situated on a "b1" axis, perpendicular to the "a1" axis, at a distance "l" from the centre of the above-mentioned central hole from which the first opening 2.4 originates towards the anterior part of the leg. The other extremity of the peripheral opening 2.5 is placed at 130-140 degrees with respect to the "b1" axis. The peripheral opening 2.5 has a particular shape: over the first 25-30 degrees starting from the afore-mentioned "b1" axis, it describes a circumference whose centre coincides with that of the hole generating the central opening and whose radius is equal to "l".

Subsequently, for the remaining 105-110 degrees, it turns into a spiral which returns towards the centre of the plate. The longitudinal axis of such spiral is obtained as the sequence of points of the end of a segment with a length "l" whose second end proceeds along the longitudinal axis of the central opening 2.4 (from the centre of the plate to the periphery).

The "a1" and "b1" axes ideally divide the proximal end of each medial tibial arm 2.2 into four quadrants; the first one is oriented towards the foot and the posterior part of the leg; the second one is oriented towards the foot and the anterior part of the leg; the third one is oriented towards the root of the lower limb and the posterior part of the leg; the fourth one is oriented towards the root of the lower limb and the anterior part of the leg.

The central opening 2.4 is placed in the two quadrants oriented towards the foot. The first peripheral opening 2.5 is placed in the two quadrants oriented towards the root of the lower limb.

The centre of a first semicircular extremity of the third opening 2.6, which is extended for 130-140 degrees, is placed at a distance "r" from the intersection of the "a1", "b1" axes in the quadrant oriented towards the foot and the anterior part of the leg, and deviates by a few degrees from the "a1" axis. The edge of the extremity of the opening 2.6 is tangential to the "a1" axis. Over the first 25-30 degrees, the opening 2.6 describes an arc of circumference, while from 25-30 degrees up to 130-140 degrees, it turns into a spiral which gets near the centre of the rounded proximal end of the medial tibial arm 2.2. More specifically, the points that make up the longitudinal axis of such spiral are at an increasingly lower distance from the centre of the rounded proximal end as they get near the second extremity.

The first tibial pin 2.7 is situated distally vis-à-vis the central opening 2.4, at a distance "r" from the intersection of the "a1", "b1" axes, in the quadrant oriented towards the foot and the posterior part of the leg. The "d2" axis which passes through the centre of the pin 2.7 and the intersection of the "a1", "b1" axes deviates by a few degrees from the "a1" axis. The peripheral edge of the

first tibial pin 2.7 is tangential to the "a1" axis and to the first extremity of the second peripheral opening 2.6.

This "d2" axis continues towards the proximal peripheral edge of the medial tibial arm 2.2. The second pin 2.8 is placed on such axis, at a distance "r" with respect to the intersection of the "a1", "b1" axes. The pin 2.8 is diametrically opposed to the pin 2.7 with respect to the "a1" axis; consequently the "d2" axis which passes through the centre of the pin 2.8 and the intersection of the "a1", "b1" axes deviates by a few degrees from the "a1" axis, though in the opposite direction. The peripheral edge of the pin 2.8 too is tangential to the "a1" axis. The pin 2.8 is placed in the quadrant oriented towards the root of the lower limb and the anterior part of the leg.

An extremity of both peripheral openings 2.5 of the tibial arms 2.1, 2.2 is situated on the "b1" axis, perpendicular to the "a1" axis. The two peripheral openings 2.5 extend towards the anterior part of the knee, in perfect symmetry to the knee itself. Similarly, the two peripheral openings 2.6 of the tibial arms 2.1, 2.2 extend towards the anterior part of the knee, in perfect symmetry to the knee itself. Similarly, the pins 2.7, 2.8 of the lateral tibial arm 2.1 are perfectly symmetrical to the pins 2.7, 2.8 of the medial tibial arm 2.2.

Similarly, the openings 1.9, 1.10 and the pins 1.6, 1.7, 1.8 of the lateral femoral arm 1.1 are perfectly symmetrical to the openings 1.9, 1.10 and to the pins 1.6, 1.7, 1.8 of the medial femoral arm 1.2.

The pins 1.5, 1.6, 1.7, 1.8, present on the medial femoral arm 1.2, are oriented towards the rounded proximal end of the medial tibial arm 2.2, whereas the pins 2.7, 2.8, present on the medial tibial arm 2.2 are oriented towards the rounded distal end of the medial femoral arm 1.2.

The central pin 1.5 of the medial femoral arm 1.2 is engaged in the central opening 2.4 of the medial tibial arm 2.2; the pin 1.6 of the medial femoral arm 1.2 is engaged in the first peripheral opening 2.5 of the medial tibial arm 2.2; the distal pin 1.8 of the medial femoral arm 1.2 is engaged in the second peripheral opening 2.6 of the medial tibial arm 2.2; the distal pin 2.7 of the

medial tibial arm 2.2 is engaged in the opening 1.9 of the medial femoral arm 1.2; the proximal pin 2.8 of the medial tibial arm 2.2 is engaged in the opening 1.10 of the medial femoral arm 1.2.

The peripheral edge of the end of the medial tibial arm 2.2, which extends in the quadrants oriented towards the posterior part of the leg, has a particular shape: the initial section of the peripheral edge 2.9 – extending in the posterior quadrant oriented towards the root of the limb – describes a circumference arc. The successive section of the peripheral edge 2.10 – extending in the posterior quadrant oriented towards the foot – is shaped as a spiral that tends to get away from the centre of the plate. More specifically, the points which make up the longitudinal axis of such spiral are situated at an increasingly greater distance from the centre of the rounded proximal end of the medial tibial arm 2.2 as they get near the second extremity. The peripheral surface of the proximal pin 1.7 of the medial femoral arm 1.2 remains in constant contact with the peripheral edge 2.9, 2.10 of the medial tibial arm 2.2 during the roto-traslatory movement of the latter vis-à-vis the medial femoral arm 1.2.

The pins 1.5, 1.6, 1.7, 1.8 and the openings 1.9, 1.10 present on the rounded distal end of the medial femoral arm 1.2, the openings 2.4, 2.5, 2.6 and the pins 2.7, 2.8 present on the rounded distal end of the medial tibial arm 2.2 make up the medial hinge of the device. Similarly, the pins 1.5, 1.6, 1.7, 1.8 and the openings 1.9, 1.10 present on the rounded distal end of the lateral femoral arm 1.1, the openings 2.4, 2.5, 2.6 and the pins 2.7, 2.8 present on the rounded distal end of the lateral tibial arm 2.1 make up the lateral hinge of the device.

The longitudinal axis of the central pin 1.5 of the lateral hinge and the longitudinal axis of the central pin 1.5 of the medial hinge are coaxial. Such axis coincides with the “c” axis which passes through the femoral condyles and around which the rotation of the knee takes place.

The pins 1.5, 1.6, 1.7, 1.8 are each provided with a threaded hole along their

longitudinal axis.

The external part of the hinge has a plate 4 with holes that are coaxial with the inner longitudinal holes of the pins 1.5, 1.6, 1.7, 1.8 of the medial femoral arm 1.2. The holes of the plate 4 accommodate the screws that engage the threaded holes of the pins 1.5, 1.6, 1.7, 1.8, thus securing the plate 4 to the medial femoral arm 1.2 and preventing disjunction of the medial tibial arm 2.2 from the medial femoral arm 1.2. The height of the pins 1.5, 1.6, 1.7, 1.8 is greater than the thickness of the medial tibial arm 2.2, which can therefore move freely between the plate 4 and the medial femoral arm 1.2.

Considering that the pins 2.7, 2.8 of the tibial arms 2.1, 2.2 and the pins 1.6, 1.7, 1.8 of the femoral arms 1.1, 1.2 are perfectly symmetrical, the plates 4 of the two hinges have perfectly symmetrical holes too.

As regards the movement in detail, the starting point is the alignment between the medial femoral arm 1.2 and the tibial arm 2.2. Under this condition, the "a" axis of symmetry of the medial femoral arm 1.2 is aligned with the "a1" axis of symmetry of the tibial arm 2.2.

During the first phase of flexion of the leg on the knee, from 0° to 30°:

- the central pin 1.5 of the medial femoral arm 1.2 rotates in the proximal extremity of the central opening 2.4 of the tibial arm 2.2 by the hole placed at the centre of the rounded proximal end of the medial tibial arm 2.2;
- the pin 1.6 of the medial femoral arm 1.2 slides in the circular part of the opening 2.5 of the medial tibial arm 2.2;
- the proximal pin 1.7 of the medial femoral arm 1.2 slides on the circular peripheral edge 2.9 of the medial tibial arm 2.2;
- the distal pin 1.8 of the medial femoral arm 1.2 slides in the circular part of the opening 2.6 of the medial tibial arm 2.2;
- the distal pin 2.7 of the medial tibial arm 2.2 slides in the circular part of the opening 1.9 of the medial femoral arm 1.2;
- the proximal pin 2.8 of the medial tibial arm 2.2 slides in the circular part of the peripheral opening 1.10 of the medial femoral arm 1.2.

In this phase of movement, the hinge performs a rotation movement similar to that of the knee during the first 30 degrees of flexion, which is generally the phase when the foot is fully on the ground.

The subject's bodyweight, which in this phase rests totally on the lower limb, is transmitted, by means of the lateral 1.1 and medial 1.2 femoral arms (secured to the thigh), to the lateral 2.1 and medial 2.2 tibial arms (secured to the leg). In particular, the bodyweight bears on the pins 1.7, 1.8 placed at the distal end of the femoral arms 1.1, 1.2 and on the pins 2.7, 2.8 placed at the proximal end of the tibial arms 2.1, 2.2.

As already pointed out, the knee joint has only two contact points: one between the femoral condyle and the tibial tray in the medial compartment (point A) and the other between the femoral condyle and the tibial tray in the lateral compartment (point B).

Thanks to the device in question, the bodyweight is distributed not only to the physiological contact points A and B, but also to the four pins of the medial hinge and to the four pins of the lateral hinge, placed on both sides of the knee itself. The four pins of each hinge transmit the load at their points of contact with the respective opening 2.6, 1.9, 1.10 and the edge 2.9.

Throughout the various phases of the movement, the specific position of each individual point of contact between pin and opening ensures the suppression of any rotation determined by the distance between the pin and the centre of the hinge.

In case of poor stability, the knee does not usually stick to a circular trajectory, thus modifying the relations between the articulation surfaces, and in particular, the vertical distance. Thanks to the device in question, a circular trajectory is preserved over the first 30 degrees, thereby avoiding a pathological overload of the knee, produced by the subject's bodyweight.

In the second phase of flexion of the leg on the thigh, from 30° to 135°:

- the central pin 1.5 of the medial femoral arm 1.2 slides along the central opening 2.4 of the medial tibial arm 2.2 and reaches its distal extremity;

- the pin 1.6 of the medial femoral arm 1.2 slides in the spiral section of the opening 2.5 of the medial tibial arm 2.2;
- the proximal pin 1.7 of the medial femoral arm 1.2 slides on the spiral peripheral edge 2.10 of the medial tibial arm 2.2;
- the distal pin 1.8 of the medial femoral arm 1.2 slides in the spiral section of the opening 2.6 of the medial tibial arm 2.2;
- the distal pin 2.7 of the medial tibial arm 2.2 slides in the spiral section of the opening 1.9 of the medial femoral arm 1.2;
- the proximal pin 2.8 of the medial tibial arm 2.2 slides in the spiral section of the peripheral opening 1.10 of the medial femoral arm 1.2.

In this phase of movement, the hinge performs a rotatory motion associated with an increasingly progressive sliding, similarly to what happens between the articulation surfaces, which – in a healthy knee – are kept in their proper relations by the cruciate ligaments. There is generally no knee overload in this phase of the movement.

In case of poor stability, however, the knee does not usually stick to a roto-traslatory trajectory, thus modifying the relations between the articulation surfaces. Particularly important to this end is therefore the guiding function imposed to the joint by the two hinges of the device through the pins 1.7, 1.8 placed at the distal end of the femoral arms 1.1, 1.2 and the pins 2.7, 2.8 placed at the proximal end of the tibial arms 2.1, 2.2.

In case of deficient anterior cruciate ligament, leading to the anterior sliding of the tibia (or posterior gliding of the femoral condyle) during flexo-extension, the pins 1.7, 2.7 can be removed, thereby generating a force component of the anterior pins 1.8, 2.8 which – by sliding in their respective openings 2.6, 1.10 – tend to break down the load bearing on the joint into a force component directed towards the centre of the hinge, thus offsetting the anterior sliding of the tibial trays. In this case the inner surface of the femoral plate 1.3 tracks the posterior part of the leg.

In case of deficient posterior cruciate ligament, leading to the posterior sliding

of the tibia (or anterior gliding of the femoral condyle) during flexo-extension, the anterior pins 1.8, 2.8 can be removed, thereby generating a force component of the posterior pins 1.7, 2.7 which – by sliding in the opening 1.9 and along the edge 2.9, 2.10 – tend to break down the load bearing on the joint into a force component directed towards the centre of the hinge, thus offsetting the posterior sliding of the tibial trays.

In a second embodiment of the present invention, the medial femoral arm 1.2 is slightly longer than the lateral femoral arm 1.1.

The tibial support 2 consists of a lateral tibial arm 2.1 and a medial tibial arm 2.2, which are parallel to one another and to the longitudinal axis of the leg. They are joined together, however, by means of an arch-shaped tibial plate 2.11 made of harmonic steel. The tibial plate 2.11, placed centrally with respect to the tibial support 2, tracks the anterior part of the leg. The symmetry axis of the tibial plate 2.11 is parallel to the symmetry axis of the femoral plate 1.3.

The medial tibial arm 2.2 consists of two parts: a fixed medial tibial arm 2.12 secured to the tibial plate 2.11 and a free-moving medial tibial arm 2.13 connected to the fixed one by means of a second medial hinge.

The free-moving medial tibial arm 2.13 consists of a rectilinear plate extended between the medial femoral arm 1.2 and the fixed medial tibial arm 2.12. The medial femoral arm 1.2 of the femoral support 1 is connected to the proximal end of the free-moving medial tibial arm 2.13 by means of the medial hinge described in the first embodiment of the present invention.

The end of the free-moving medial tibial arm 2.13 connected to the first medial hinge has the shape of a plate and accommodates the three afore-mentioned openings 2.4, 2.5, 2.6 as well as the two pins 2.7, 2.8. The pins 1.5, 1.6, 1.7, 1.8 and the openings 1.9, 1.10 present on the rounded distal end of the medial femoral arm 1.2, the openings 2.4, 2.5, 2.6 and the pins 2.7, 2.8 present on the rounded proximal end of the free-moving medial tibial arm 2.13 make up the medial hinge of the device. In this case too, the peripheral

edge 2.9, 2.10 of the end of the free-moving medial tibial arm 2.13, which extends in the quadrants oriented towards the posterior part of the leg, has a particular shape. The peripheral surface of the proximal pin 1.7 of the medial femoral arm 1.2 remains in constant contact with the peripheral edge 2.9, 2.10 of the free-moving medial tibial arm 2.13 during the roto-traslatory movement of the latter with respect to the medial femoral arm 1.2.

The distal end of the free-moving medial tibial arm 2.13 is rounded and has a hole 2.14 on the symmetry axis of the free-moving medial tibial arm 2.13 itself, which is engaged by a pin 2.15 situated at the intersection between the symmetry axis of the tibial plate 2.11 and the symmetry axis of the fixed medial tibial arm 2.12.

The plate present on the proximal end of the lateral tibial arm 2.1 accommodates the three afore-mentioned openings 2.4, 2.5 e 2.6. The two pins 2.7, 2.8 are also secured to the plate itself. The pins 1.5, 1.6, 1.7, 1.8 and the openings 1.9, 1.10 present on the rounded distal end of the lateral femoral arm 1.1, the openings 2.4, 2.5, 2.6 and the pins 2.7, 2.8 present on the rounded proximal end of the lateral tibial arm 2.1 make up the lateral hinge of the device.

There are, however, some differences between the two peripheral openings 2.5 situated respectively on the lateral tibial arm 2.1 of the tibial support 2 and on the free-moving medial tibial arm 2.13. The circular part of the peripheral opening 2.5 situated on the free-moving medial tibial arm 2.13 has a width of about 15°-20°, while the circular part of the opening 2.5 situated on the lateral tibial arm 2.1 has a width of about 25°-30°. The spiral-shaped part of the peripheral opening 2.5 of the free-moving medial tibial arm 2.13 extends for about 115°-120°, whereas that of the peripheral opening 2.5 situated on the lateral tibial arm 2.1 extends for about 105°-110°. Furthermore, the spiral-shaped part of the peripheral opening 2.5 of the lateral tibial arm 2.1 returns towards the centre of the plate to a greater extent than the spiral-shaped part of the peripheral opening 2.5 of the free-moving medial tibial arm 2.13. The

exact extent of this return – to be arranged at the time of construction of the peripheral opening 2.5 of the free-moving medial tibial arm 2.13 – can be established as a result of a radiological study or anthropometric evaluation.

Similarly, the opening 2.6 situated on the free-moving medial tibial arm 2.13 presents a different shape from that of the lateral tibial arm 2.1. The circular part of the peripheral opening 2.6 situated on the free-moving medial tibial arm 2.13 has a width of about 15°-20°, whereas the circular part of the opening 2.6 situated on the lateral tibial arm 2.1 has a width of about 25°-30°. The spiral-shaped part of the peripheral opening 2.6 of the free-moving medial tibial arm 2.13 extends for about 115°-120°, whereas that of the peripheral opening 2.6 situated on the lateral tibial arm 2.1 extends for about 105°-110°. Moreover, the spiral-shaped part of the peripheral opening 2.6 of the lateral tibial arm 2.1 returns towards the centre of the plate to a greater extent than the spiral-shaped part of the peripheral opening 2.6 of the free-moving medial tibial arm 2.13. The opening 2.4 of the lateral tibial arm 2.1 is more elongated than the opening of the free-moving medial tibial arm 2.13.

The central opening 2.4 of the plate of the free-moving medial tibial arm 2.13 is engaged by the central pin 1.5 of the medial femoral arm 1.2. The peripheral opening 2.5 of the plate of the free-moving medial tibial arm 2.13 is engaged by the peripheral pin 1.6 of the medial femoral arm 1.2. The peripheral opening 2.6 of the plate of the free-moving medial tibial arm 2.13 is engaged by the peripheral pin 1.8 of the medial femoral arm 1.2.

The openings 1.9 and 1.10 placed on the lateral femoral arm 1.1 are different from the openings 1.9 and 1.10 placed on the medial femoral arm 1.2. The circular part of the opening 1.9 situated on the lateral femoral arm 1.1 has a width of about 25°-30°, whereas the circular part of the opening 1.9 situated on the medial femoral arm 1.2 has a width of about 15°-20°. The spiral-shaped part of the opening 1.9 situated on the lateral femoral arm 1.1 extends for about 105°-110°, whereas the spiral-shaped part of the opening 1.9 situated on the medial femoral arm 1.2 extends for about 115°-120°.

The spiral-shaped part of the opening 1.9 situated on the medial femoral arm 1.2 returns to a lesser extent towards the centre of the plate with respect to the opening 1.9 situated on the lateral femoral arm 1.1. The spiral-shaped part of the opening 1.10 situated on the medial femoral arm 1.2 returns to a greater extent towards the centre of the plate with respect to the opening 1.10 situated on the lateral femoral arm 1.1. The arc-shaped peripheral edge 2.9 present on the end of the free-moving medial tibial arm 2.13 has a width of about 15-20°, whereas the one present on the lateral tibial arm 2.1 has a width of about 25-30°. The spiral-shaped peripheral edge 2.10 present on the end of the free-moving medial tibial arm 2.13 has a width of 115°-120°, whereas the one present on the lateral tibial arm 2.1 has a width of 105°-110°. The spiral-shaped part of the peripheral edge 2.10 situated on the free-moving medial tibial arm 2.13 returns to a greater extent towards the centre of the plate itself with respect to the spiral-shaped part of the peripheral edge 2.10 situated on the lateral tibial arm 2.1.

An arc-shaped opening 2.16, with rounded extremities, is placed on the symmetry axis of the free-moving medial tibial arm 2.13, in a proximal position vis-à-vis the hole 2.14. The centre of an extremity of the opening 2.16 is placed on the symmetry axis of the free-moving medial tibial arm 2.13. The opening 2.16 extends in anterior direction.

Such opening 2.16 is engaged by a second pin 2.17, which is secured to the fixed medial tibial arm 2.12 and is placed proximally with respect to the pin 2.15 on the symmetry axis of the fixed medial tibial arm 2.12 itself. The pins 2.15, 2.17 have each a threaded hole along their longitudinal axis.

The two due pins 2.15, 2.17 secured to the fixed medial tibial arm 2.12, the hole 2.14 and the arc-shaped opening 2.16 of the free-moving medial tibial arm 2.13 make up the second medial hinge.

The second medial hinge too presents externally a plate 5 with holes, which are coaxial with the inner longitudinal holes of the pins 2.15, 2.17 of the fixed medial tibial arm 2.12. The holes of the plate 5 accommodate the screws

which then engage the threaded holes of the pins 2.15, 2.17, securing the plate 5 to the fixed medial tibial arm 2.12 and avoiding the disjunction of the free-moving medial tibial arm 2.13 from the fixed medial tibial arm 2.12. The height of the pins 2.15, 2.17 is greater than the thickness of the free-moving medial tibial arm 2.13, which can therefore move freely between the plate 5 and the fixed medial tibial arm 2.12.

The difference of shape between the openings 2.4, 2.5, 2.6 situated on the free-moving medial tibial arm 2.13 and those situated on the lateral tibial arm 2.1 determines a difference of trajectory between the free-moving medial tibial arm 2.13 and the lateral tibial arm 2.1. The lateral tibial arm 2.1 imposes its trajectory to the fixed medial tibial arm 2.12 to which it is connected by means of the tibial plate 2.11.

During the flexion from 0 to 15-20 degrees, the symmetry axis of the free-moving medial tibial arm 2.13 is coaxial to the symmetry axis of the fixed medial tibial arm 2.12. Both are parallel to the symmetry axis of the lateral tibial arm 2.1.

From 15-20° to 135° of flexion, the symmetry axis of free-moving medial tibial arm 2.13 changes its angle with respect to that of the symmetry axis of the fixed medial tibial arm 2.12. The free-moving medial tibial arm 2.13 starts a roto-traslatory trajectory, imposed by its openings 2.5, 2.6, while the fixed medial tibial arm 2.12 remains on a circular trajectory as the openings 2.5, 2.6 of the lateral tibial arm 2.1 are arc-shaped up to 30 degrees.

The fulcrum of such change of angle between the symmetry axes lies in the pin 2.15 of the fixed medial tibial arm 2.12, which rotates within the hole 2.14 of the free-moving medial tibial arm 2.13 in which it is engaged, whereas the pin 2.17 of the fixed medial tibial arm 2.12 slides in the opening 2.16 of the free-moving medial tibial arm 2.13.

Similarly to what happens in the human knee, the device in question can track the automatic longitudinal rotation of the tibia.

This physiological motion makes the leg and the respective foot rotate

externally, thus modifying also the position of the longitudinal axes of the leg itself, which remain always parallel to one another.

The same parallel pattern between the lateral tibial arm 2.1 and the fixed medial tibial arm 2.12 is preserved by the device, which, however, can rotate during flexo-extension by an extent equal to the cosine of the angle formed between the symmetry axis del free-moving medial tibial arm 2.13 and the symmetry axis of the fixed medial tibial arm 2.12, multiplied by the length comprised between the intersection of the "a1", "b1" axes lying on the free-moving medial tibial arm 2.13 and the centre of the hole 2.14, which is engaged by the pin 2.15, situated on the fixed medial tibial arm 2.12, in such a way that the symmetry axis of the fixed medial tibial arm 2.12 and the symmetry axis of the lateral tibial arm 2.1 are always perfectly superimposed to the respective longitudinal axes of the leg, to which they are secured.

The angle of longitudinal rotation can be modified by changing the distance between the intersection of the "a1", "b1" axes lying on the free-moving medial tibial arm 2.13 and the centre of the pin 2.15 of the fixed medial tibial arm 2.12, which must be equal to the distance between the intersection of the "a1", "b1" axes lying on the lateral tibial arm 2.1 and the point of intersection between the symmetry axis of the tibial plate 2.11 and the symmetry axis of the lateral tibial arm 2.1.

In order to improve the adjustment of the device, the distal end of the free-moving medial tibial arm 2.13 accommodate three holes 2.18 along its symmetry axis and three arc-shaped openings 2.19. The position of the free-moving medial tibial arm 2.13 can thus be adjusted with respect to the tibial plate 2.11 by changing the holes 2.18 and the openings 2.19 which are engaged by the pins 2.15, 2.17 of the fixed medial tibial arm 2.12 .

In order to further increase the adjustment of the device in question, the lateral tibial arm 2.1 too consists of a proximal lateral tibial arm 2.20 and a distal lateral tibial arm 2.21. The proximal lateral tibial arm 2.20 has an elongated shape and the distal lateral tibial arm 2.21 is secured to the tibial

plate 2.11. Three equidistant holes 2.22 are situated on the prolongation of the proximal lateral tibial arm 2.20 and along its symmetry axis. The distal lateral tibial arm 2.21 accommodates two threaded holes 2.23, coaxial to at least two holes 2.22 present on the proximal lateral tibial arm 2.20. Two screws pass through the holes 2.22 of the proximal lateral tibial arm 2.20 and engage the two threaded holes 2.23 of the distal lateral tibial arm 2.21. The position of the distal lateral arm 2.21 can thus be adjusted with respect to the tibial plate 2.11 by allowing the screws to engage at each time different holes 2.23 of the distal lateral tibial arm 2.21.

CLAIMS

1 - Ergonomic knee device aimed at breaking down the vertical loads, consisting of a femoral support (1) and a tibial support (2); said femoral support (1) comprises a lateral femoral arm (1.1) and a medial femoral arm (1.2), which are parallel to one another and to the longitudinal axis of the thigh and are joined together by length-adjustable fasteners that can secure the femoral support (1) to the thigh; said tibial support (2) comprises a lateral tibial arm (2.1) and at least one medial tibial arm (2.2, 2.12, 2.13), which are parallel to one another and to the longitudinal axis of the leg; said femoral arms (1.1, 1.2) and tibial arms (2.2, 2.12) are secured to the thigh and the leg respectively by straps (3), which have a nylon/Velcro® face and pass through linear openings (1.4, 2.3) made on the femoral arms (1.1, 1.2) and tibial arms (2.1, 2.2), and by a plate (1.3, 2.11); said plate (1.3), made of rigid or semirigid material and arc-shaped, tracks – with its inner surface – the anterior part of the thigh; the distal ends of the femoral arms (1.1, 1.2) and the proximal ends of the tibial arms (2.1, 2.2, 2.13) are joined together by at least two hinges, one placed laterally and the other medially with respect to the knee; the distal ends of each femoral arm (1.1, 1.2) and the proximal ones of each tibial arm (2.1, 2.2, 2.13), which make up the hinges, are plate-shaped and rounded; said device is characterized by the fact the rounded distal end of each femoral arm (1.1, 1.2) accommodates four pins (1.5, 1.6, 1.7, 1.8) and two openings (1.9, 1.10); the first pin (1.5) is placed on the distal end of each femoral arm (1.1, 1.2) in a central position along the “a” axis which coincides with the longitudinal symmetry axis of the femoral arm (1.1, 1.2) itself; the second pin (1.6) is placed on the distal end of each femoral arm (1.1, 1.2) in a peripheral position and at a distance “l” with respect to the central pin (1.5), along the “b” axis, perpendicular to the “a” axis; the “a” and “b” axes divide ideally the distal end of the lateral femoral arm (1.1) and of the medial femoral arm (1.2) into four quadrants: the first one oriented towards the foot and the posterior part of the leg; the second one oriented towards the foot and the

anterior part of the leg; the third one oriented towards the root of the lower limb and the posterior part of the leg; the fourth one oriented towards the root of the lower limb and the anterior part of the leg; a third pin (1.7) is situated proximally with respect to the afore-mentioned pins (1.5, 1.6) and in the quadrant oriented towards the root of the lower limb and the posterior part of the leg; said proximal pin (1.7) is placed at a distance "r" with respect to the central pin (1.5); the "d" axis, which passes through the centre of the proximal pin (1.7) and the centre of the central pin (1.5), deviates by a few degrees from the "a" axis, and the peripheral edge of the proximal pin (1.7) is tangential to the "a" axis itself; said fourth pin (1.8) is situated in the quadrant oriented towards the foot and the anterior part of the leg, on the prolongation of said "d" axis at a distance "r" with respect to the central pin (1.5); the peripheral edge of the distal pin (1.8) is tangential to the "a" axis and is diametrically opposed to the proximal pin (1.7) with respect to the central pin (1.5); said first opening (1.9) is situated near the peripheral edge of the rounded distal end of each femoral arm (1.1, 1.2) and extends into the two quadrants oriented towards the posterior part of the leg for 130°-140 degrees; the centre of a first semicircular extremity of the opening (1.9) is placed at a distance "r" from the central pin (1.5) along the "d1" axis, which is perfectly symmetrical to the "d" axis vis-à-vis the "a" axis; the edge of the first semicircular extremity of said first opening (1.9) is tangential to the "a" axis and to the peripheral edge of the distal pin (1.8); starting from said first extremity over the first 25-30 degrees, said first opening (1.9) has the shape of an arc of circumference; from 25-30 degrees up to 130-140 degrees, said first opening (1.9) has the shape of a spiral which gets near the centre of the rounded distal end of the lateral femoral arm (1.1) and of the medial femoral arm (1.2); said second opening (1.10) is diametrically opposed to said first opening (1.9) with respect to the "a" axis and is placed in the two quadrants oriented towards the anterior part of the leg; the centre of a first extremity of said second opening (1.10) is placed at a distance "r" from the central pin

(1.5) along said "d1" axis; the edge of the first semicircular extremity of said second opening (1.10) is tangential to the "a" axis and to the peripheral edge of the proximal pin (1.7); starting from said first semicircular extremity for the first 25-30 degrees, said second opening (1.10) has the shape of an arc of circumference; from 25-30 degrees up to 130-140 degrees, said second opening (1.10) has the shape of a spiral that, unlike the first opening (1.9), gets away from the centre of the rounded distal end of the femoral arm (1.1 1.2); the plate present on the proximal end of each tibial arm (2.1, 2.2, 2.13) accommodates three openings (2.4, 2.5, 2.6) and two pins (2.7, 2.8); the first tibial opening (2.4) has a rectangular shape with rounded extremities and is obtained by making a hole at the centre of the plate of the proximal end of the medial tibial arm (2.1, 2.2, 2.13) and proceeding towards the foot along the "a1" axis of longitudinal symmetry of the tibial arm (2.1, 2.2, 2.13); the second opening (2.5) extends for about 130-140 degrees and is placed peripherally on the proximal end of each tibial arm (2.1, 2.2, 2.13); a first extremity of such second peripheral opening (2.5) is situated on the "b1" axis, perpendicular to the "a1" axis, at a distance "l" from the centre of the afore-mentioned central hole, which originates the first opening (2.4); the other extremity of the second tibial opening (2.5) is placed at 130-140 degrees with respect to the "b1" axis; starting from said "b1" axis, for the first 25-30 degrees, said second tibial opening (2.5) has the shape of an arc of circumference whose centre coincides with that of the hole generating the central tibial opening (2.4) and whose radius is equal to "l"; from 25-30 degrees to the remaining 105-110 degrees said second tibial opening (2.5) has the shape of a spiral that returns towards the centre of the proximal end of each tibial arm (2.1, 2.2, 2.13); the longitudinal axis of said spiral is the result of the sequence of points covered by the extremity of a segment having a length "l" whose second extremity travels along the longitudinal axis of the central opening (2.4) from the centre of each tibial arm (2.1, 2.2, 2.13) to the periphery; the afore-mentioned "a1" axis and the afore-mentioned "b1" axis ideally divide the proximal end of each

tibial arm (2.1, 2.2, 2.13) into four quadrants: the first one oriented towards the foot and the posterior part of the leg; the second one oriented towards the foot and the anterior part of the leg; the third one oriented towards the root of the lower limb and the posterior part of the leg; the fourth one oriented towards the root of the lower limb and the anterior part of the leg; said central tibial opening (2.4) is placed in the two quadrants oriented towards the foot, whereas said second tibial opening (2.5) is placed in the two quadrants oriented towards the root of the lower limb; the centre of a first semicircular extremity of the third opening (2.6) is situated at a distance "r" from the intersection of the "a1", "b1" axes in the quadrant oriented towards the foot and the anterior part of the leg, and deviates by a few degrees from the "a1" axis; the edge of the extremity of said third tibial opening (2.6) is tangential to the "a1" axis; said third tibial opening (2.6) extends for about 130-140 degrees and has the shape of an arc of circumference for the first 25-30 degrees, while from 25-30 degrees up to 130-140 degrees it describes a spiral which gets near the centre of the rounded proximal end of each tibial arm (2.1, 2.2, 2.13); the first tibial pin (2.7) is placed distally with respect to the central opening (2.4) and at a distance "r" from the intersection of the a1", "b1" axes in the quadrant oriented towards the foot and the posterior part of the leg; the "d2" axis, which passes through the centre of the pin (2.7) and the intersection of the "a1", "b1" axes, deviates by a few degrees from the "a1" axis; the peripheral edge of the first tibial pin (2.7) is tangential to the "a1" axis itself and to the first extremity of the third tibial opening (2.6); said "d2" axis extends towards the proximal peripheral edge of the medial tibial arm (2.2); a second tibial pin (2.8) is placed on such "d2" axis at a distance "r" with respect to the intersection of the "a1", "b1" axes; said second tibial pin (2.8) is diametrically opposed to the first tibial pin (2.7) vis-à-vis the "a1" axis, consequently the "d2" axis, which passes through the centre of the pin (2.8) and the intersection of the "a1", "b1" axes, deviates by a few degrees from the "a1" axis though in the opposite direction; the peripheral edge of the second

tibial pin (2.8) too is tangential to the "a1" axis; said second proximal tibial pin (2.8) is placed in the quadrant oriented towards the root of the lower limb and the anterior part of the leg; an extremity of both peripheral openings (2.5) of the tibial arms (2.1, 2.2, 2.13) is situated on the "b1" axis, perpendicular to the "a1" axis; the two peripheral openings (2.5) extend towards the anterior part of the knee and are perfectly symmetrical to the knee itself; the two peripheral openings (2.6) of the tibial arms (2.1, 2.2, 2.13) too extend towards the anterior part of the knee and are perfectly symmetrical to the knee itself; similarly, the pins (2.7, 2.8) of the lateral tibial arm (2.1) are perfectly symmetrical to the pins (2.7, 2.8) of the medial tibial arm (2.2, 2.13), and the openings (1.9, 1.10) and the pins (1.6, 1.7, 1.8) of the lateral femoral arm (1.1) are perfectly symmetrical to the openings (1.9, 1.10) and the pins (1.6, 1.7, 1.8) of the medial femoral arm (1.2); said pins (1.5, 1.6, 1.7, 1.8) present on each femoral arm (1.1, 1.2) are oriented towards the rounded proximal end of each tibial arm (2.1, 2.2, 2.13), whereas the pins (2.7, 2.8) present on each tibial arm (2.1, 2.2, 2.13) are oriented towards the rounded distal end of each femoral arm (1.1, 1.2); the first part of the peripheral edge (2.9) of the end of each tibial arm (2.1, 2.2, 2.13), which extends in the quadrant oriented towards the root of the lower limb, has the shape of an arc of circumference; in its second part, which extends in the posterior quadrant oriented towards the foot, the peripheral edge (2.10) has the shape of a spiral which tends to get away with respect to the centre of the end of each tibial arm (2.1, 2.2, 2.13); the peripheral surface of said proximal pin (1.7) of each femoral arm (1.1, 1.2) remains in constant contact with the peripheral edge (2.9, 2.10) of each tibial arm (2.1, 2.2, 2.13) during the roto-traslatory movement of the latter with respect to each femoral arm (1.1, 1.2); the central pin (1.5) of each femoral arm (1.1, 1.2) engages the central opening (2.4) of each tibial arm (2.1, 2.2, 2.13); the second pin (1.6) of each femoral arm (1.1, 1.2) engages the first peripheral opening (2.5) of each tibial arm (2.1, 2.2, 2.13); the distal pin (1.8) of each femoral arm (1.1, 1.2) engages the second peripheral

opening (2.6) of each tibial arm (2.1, 2.2, 2.13); the distal pin (2.7) of each tibial arm (2.1, 2.2, 2.13) engages the first opening (1.9) of each femoral arm (1.1, 1.2), and the proximal pin (2.8) of each tibial arm (2.1, 2.2, 2.13) engages the second opening (1.10) of each femoral arm (1.1, 1.2); the pins (1.5, 1.6, 1.7, 1.8) and the openings (1.9, 1.10) present on the rounded distal end of the lateral femoral arm (1.1) and the openings (2.4, 2.5, 2.6) and the pins (2.7, 2.8) present on the rounded proximal end of the lateral tibial arm (2.1) make up a lateral hinge of the device; similarly, the pins (1.5, 1.6, 1.7, 1.8) and the openings (1.9, 1.10) present on the rounded distal end of the medial femoral arm (1.2), the openings (2.4, 2.5, 2.6) and the pins (2.7, 2.8) present on the rounded proximal end of the medial tibial arm (2.2, 2.13) make up a medial hinge of the device; said pins (1.5, 1.6, 1.7, 1.8) of the distal ends of the femoral arms (1.1, 1.2) are secured to a plate (4) placed externally to each tibial arm (2.1, 2.2, 2.13) by means of fasteners; each plate (4) is provided with holes that are coaxial with the pins (1.5, 1.6, 1.7, 1.8) of each femoral arm (1.1, 1.2); said holes of the plate (4) accommodate the free ends of the pins (1.5, 1.6, 1.7, 1.8) themselves or the afore-mentioned fasteners which engage the pins (1.5, 1.6, 1.7, 1.8), thus securing each plate (4) to each femoral arm (1.1, 1.2) and avoiding its disjunction from the respective tibial arm (2.1, 2.2, 2.13); the height of the afore-mentioned pins (1.5, 1.6, 1.7, 1.8) is greater than the thickness of each tibial arm (2.1, 2.2, 2. 13) so that the latter can move freely between the plate (4) and the femoral arm (1.1, 1.2).

2 - Knee ergonomic device, in accordance with claim 1, characterized by the fact that the lateral tibial arm (2.1) and the medial tibial arm are joined together by an arch-shaped tibial plate (2.11), made of rigid material with a good harmonic response like harmonic steel; said tibial plate (2.11), placed in central position with respect to the tibial support (2), tracks the anterior part of the leg; the symmetry axis of the tibial plate (2.11) is parallel to the symmetry axis of the femoral plate (1.3); the medial tibial arm consists of two parts: a fixed medial tibial arm (2.12) secured to the tibial plate (2.11) and a free-

moving medial tibial arm (2.13) secured to the fixed medial tibial arm (2.12) by means of a second medial hinge; the free-moving medial tibial arm (2.13) consists of a rectilinear plate which extends between the medial femoral arm (1.2) and the fixed medial tibial arm (2.12); the fixed medial femoral arm (1.2) of the femoral support (1) is connected to the proximal end of the free-moving medial tibial arm (2.13) by means of a medial hinge comprising the pins (1.5, 1.6, 1.7, 1.8) and the openings (1.9, 1.10) present on the rounded distal end of the medial femoral arm (1.2), as well as the openings (2.4, 2.5, 2.6) and the pins (2.7, 2.8) present on the rounded proximal end of the free-moving medial tibial arm (2.13); the distal end of the free-moving medial arm (2.13) is rounded and is provided with a hole (2.14) situated on the symmetry axis of the free-moving medial tibial arm (2.13) itself, which is engaged by a pin (2.15) placed at the intersection between the symmetry axis of the tibial plate (2.11) and the symmetry axis of the fixed medial tibial arm (2.12); an opening (2.16), which has the shape of a circumference arc and has rounded extremities, is placed on the symmetry axis of the free-moving medial tibial arm (2.13), proximally to the hole (2.14); the centre of an extremity of the opening (2.16) is situated on the symmetry axis of the free-moving medial tibial arm (2.13); the opening (2.16) extends anteriorly to the knee; said opening (2.16) accommodates a second pin (2.17), secured to the fixed medial tibial arm (2.12) and placed proximally with respect to the pin (2.15) on the symmetry axis of the fixed medial tibial arm (2.12) itself; the two pins (2.15, 2.17) secured to the fixed medial tibial arm (2.12), the hole (2.14) and the arc-shaped opening (2.16) of the free-moving medial tibial arm (2.13) make up a second medial hinge; said pins (2.15, 2.17) of the fixed medial tibial arm (2.12) are secured to an external plate (5) by means of fasteners; the plate (5) is provided with holes coaxial with the pins (2.15, 2.17); said holes of the plate (5) accommodate the free ends of the pins (2.15, 2.17) themselves or the afore-mentioned fasteners which engage the pins (2.15, 2.17), securing the plate (5) to the fixed medial tibial arm (2.12) and

preventing the disjunction of the free-moving medial tibial arm (2.13) from the fixed medial tibial arm (2.12); the height of the afore-mentioned pins (2.15, 2.17) is greater than the thickness of the free-moving medial tibial arm (2.13), which can consequently travel freely between the plate (5) and the fixed medial tibial arm (2.12); the medial femoral arm (1.2) is slightly longer than the lateral femoral arm (1.1).

3 - Knee ergonomic device, in accordance with the claim 2, characterized by the fact that the circular part of the peripheral opening (2.5) situated on the free-moving medial tibial arm (2.13) has a width of about 15°-20°, whereas the circular part of the opening (2.5) situated on the lateral tibial arm (2.1) has a width of about 25°-30°; the spiral-shaped part of the peripheral opening (2.5) of the free-moving medial tibial arm (2.13) extends for about 115°-120°, whereas that of the peripheral opening (2.5) situated on the lateral tibial arm (2.1) extends for about105°-110°; the spiral-shaped part of the peripheral opening (2.5) of the lateral tibial arm (2.1) returns towards the centre of the plate to a greater extent compared to the spiral-shaped part of the peripheral opening (2.5) of the free-moving medial tibial arm (2.13); the circular part of the peripheral opening (2.6) situated on the free-moving medial tibial arm (2.13) has a width of about 15°-20°, whereas the circular part of the opening (2.6) situated on the lateral tibial arm (2.1) has a width of about 25°-30°; the spiral-shaped part of the peripheral opening (2.6) of the free-moving medial tibial arm (2.13) extends for about 115°-120°, whereas that of the peripheral opening (2.6) situated on the lateral tibial arm (2.1) extends for about 105°-110°; the spiral-shaped part of the peripheral opening (2.6) of the lateral tibial arm (2.1) returns towards the centre of the plate to a greater extent compared to the spiral-shaped part of the peripheral opening (2.6) of the free-moving medial tibial arm (2.13); the opening (2.4) of the lateral tibial arm (2.1) has a more elongated shape than the opening of the free-moving medial tibial arm (2.13); the circular part of the opening (1.9) situated on the lateral femoral arm (1.1) has a width of about 25°-30°, whereas the circular part of the opening

(1.9) situated on the medial femoral arm (1.2) has a width of about 15°-20°; the spiral-shaped part of the opening (1.9) situated on the lateral femoral arm (1.1) extends for about 105°-110°, whereas the spiral-shaped part of the opening (1.9) situated on the medial femoral arm (1.2) extends for about 115°-120°; the spiral-shaped part of the peripheral opening (1.9) of the lateral femoral arm (1.1) returns towards the centre of the plate to a greater extent compared to the spiral-shaped part of the peripheral opening (1.9) of the medial femoral arm (1.2); the circular part of the opening (1.10) situated on the lateral femoral arm (1.1) has a width of about 25°-30°, whereas the circular part of the opening (1.10) situated on the medial femoral arm (1.2) has a width of about 15°-20°; the spiral-shaped part of the opening (1.10) situated on the lateral femoral arm (1.1) extends for about105°-110°, whereas the spiral-shaped part of the opening (1.10) situated on the medial femoral arm (1.2) extends for about 115°-120°; the spiral-shaped part of the peripheral opening (1.10) of the lateral femoral arm (1.1) returns towards the centre of the plate to a lesser extent compared to the spiral-shaped part of the peripheral opening (1.10) of the medial femoral arm (1.2); the arc-shaped peripheral edge (2.9) present on the end of the free-moving medial tibial arm (2.13) has a width of 15-20°, whereas the one present on the lateral tibial arm (2.1) has a width of 25-30°; the spiral-shaped peripheral edge (2.10) present on the end of the free-moving medial tibial arm (2.13) has a width of 115°-120°, whereas the one present on the lateral tibial arm (2.1) has a width of 105°-110°; the spiral-shaped part of the peripheral edge (2.10) situated on the free-moving medial tibial arm (2.13) returns towards the centre of the plate itself to a greater extent compared to the spiral-shaped peripheral edge (2.10) situated on the lateral tibial arm (2.1).

4 - Knee ergonomic device, in accordance with the claims 1 and 2, characterized by the fact the pins (1.5, 1.6, 1.7, 1.8) of the distal ends of the femoral arms (1.1, 1.2) and the pins (2.15, 2.17) of the fixed medial tibial arm (2.12) are each provided with a threaded hole along their longitudinal axis;

said holes of the plates (4, 5) accommodate the screws that engage the threaded holes of the pins (1.5, 1.6, 1.7, 1.8, 2.15, 2.17).

5 - Ergonomic knee device, in accordance with the claims 1 and 2, characterized by the fact the pins (1.5, 1.6, 1.7, 1.8) of the distal ends of the femoral arms (1.1, 1.2) and the pins (2.15, 2.17) of the fixed medial tibial arm (2.12) are each provided with a hole along their longitudinal axis; the holes of the plates (4, 5) accommodate the rivets whose free end engages the holes of the pins (1.5, 1.6, 1.7, 1.8, 2.15, 2.17).

6 - Ergonomic knee device, in accordance with the claims 1 and 2, characterized by the fact the pins (1.5, 1.6, 1.7, 1.8) of the distal ends of the femoral arms (1.1, 1.2) and the pins (2.15, 2.17) of the fixed medial tibial arm (2.12) are each provided with an external thread on their free end; each one of said threads is engaged by a nut.

7 - Ergonomic knee device, in accordance with the claim 1, characterized by the fact the pins (1.5, 1.6, 1.7, 1.8, 2.15, 2.17) of the femoral arms (1.1, 1.2) and of the medial tibial arms (2.1, 2.2, 2.13) can be removed in the presence of specific pathologies.

8 - Ergonomic knee device, in accordance with the claim 2, characterized by the fact the tibial plate (2.11) can be connected to each tibial arm (2.2, 2.3) by means of a fastener.

9 - Ergonomic knee device, in accordance with the claim 2, characterized by the fact the distal end of the free-moving medial tibial arm (2.13) accommodates multiple holes (2.18) along its symmetry axis and multiple arc-shaped openings (2.19); the centre of a semicircular extremity of the openings (2.19) is placed along the same symmetry axis.

10 - Ergonomic knee device, in accordance with the claim 2, characterized by the fact the lateral tibial arm consists of a proximal lateral tibial arm (2.20) and a distal lateral tibial arm (2.21); the proximal lateral tibial arm (2.20) has an elongated shape and the distal lateral tibial arm (2.21) is secured to the tibial plate (2.11); at least three equidistant holes (2.22) are placed on the

prolongation of the proximal lateral tibial arm (2.20) and along its symmetry axis; at least two threaded holes (2.23) are placed on the distal lateral tibial arm (2.21) and are coaxial to at least two holes (2.22) present on the proximal lateral tibial arm (2.20); two screws engage the holes (2.22) of the proximal lateral tibial arm (2.20) and are secured in the two threaded holes (2.23) of the distal lateral tibial arm (2.21).

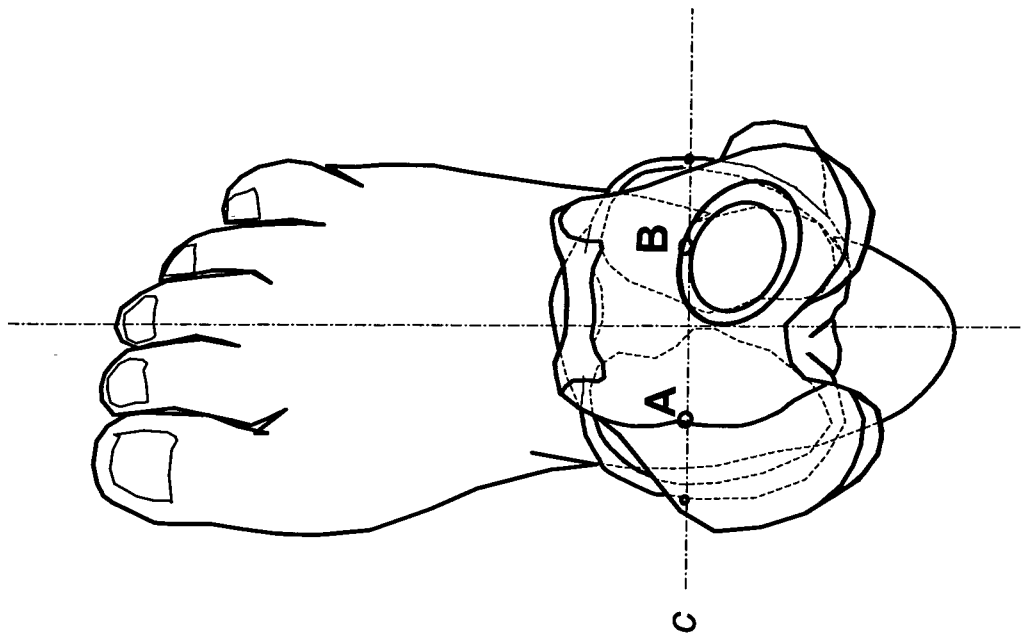


Fig. 2

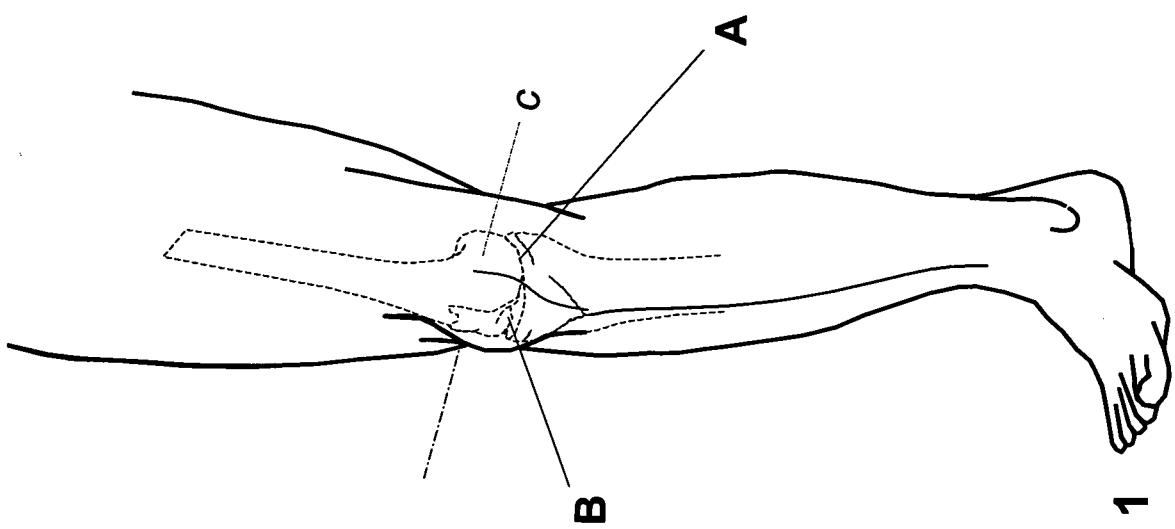


Fig. 1

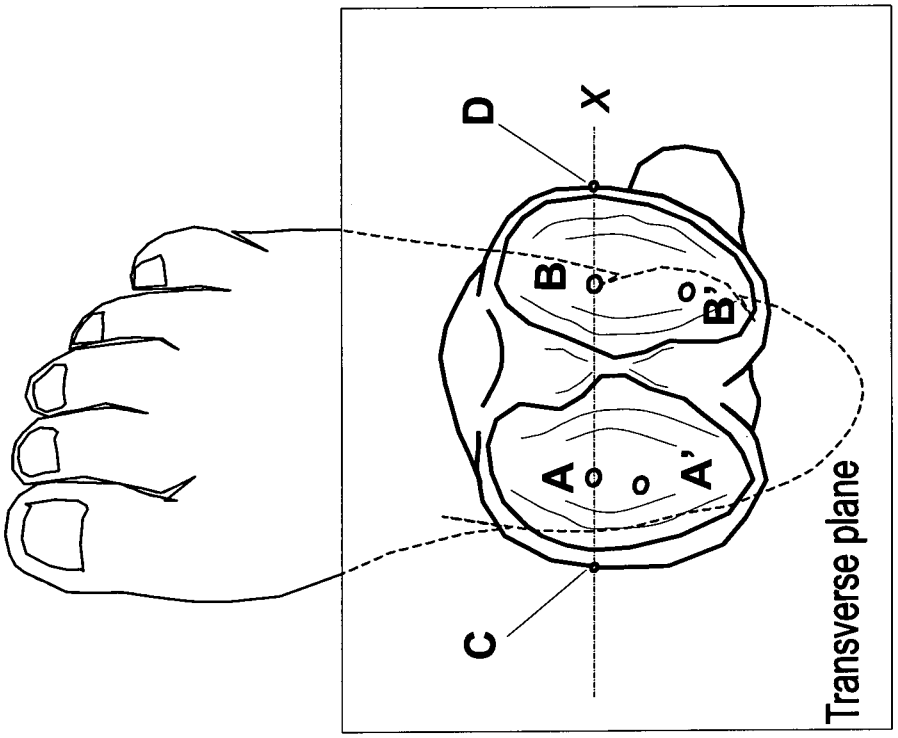

D
X
B
B'
A
A'
C
Transverse plane

Fig.4

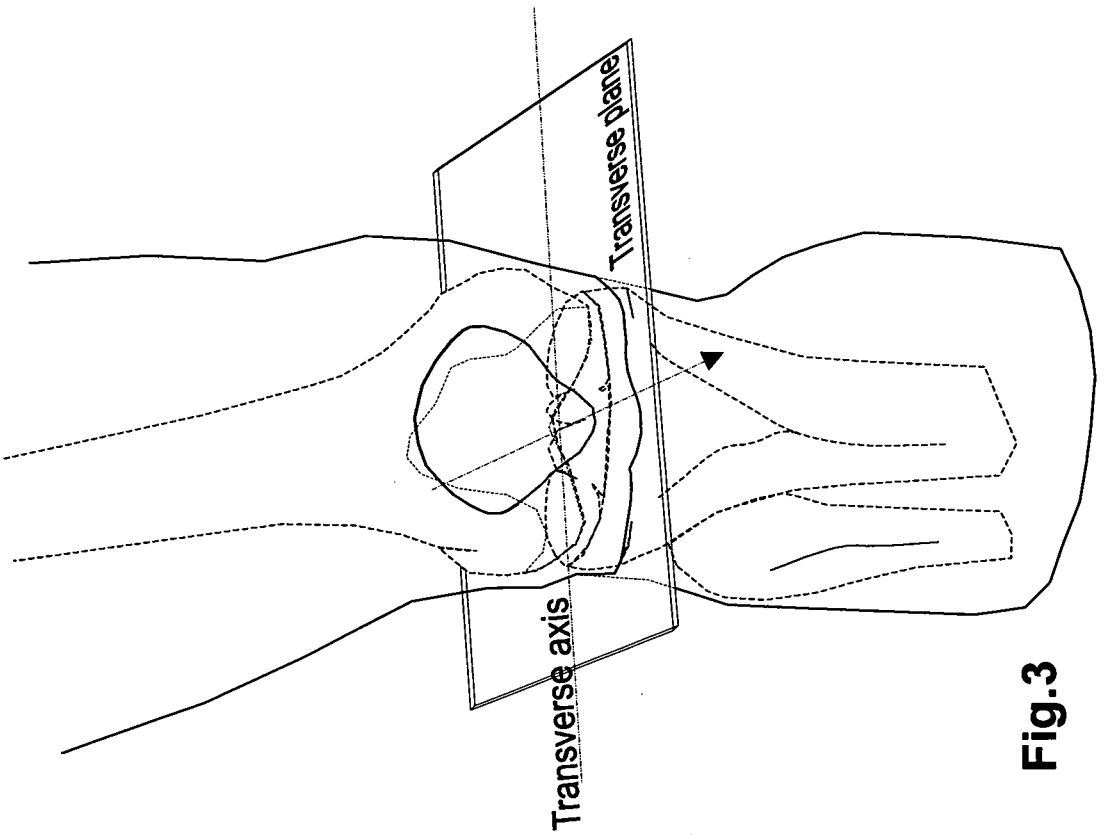

Transverse plane
Transverse axis

Fig.3

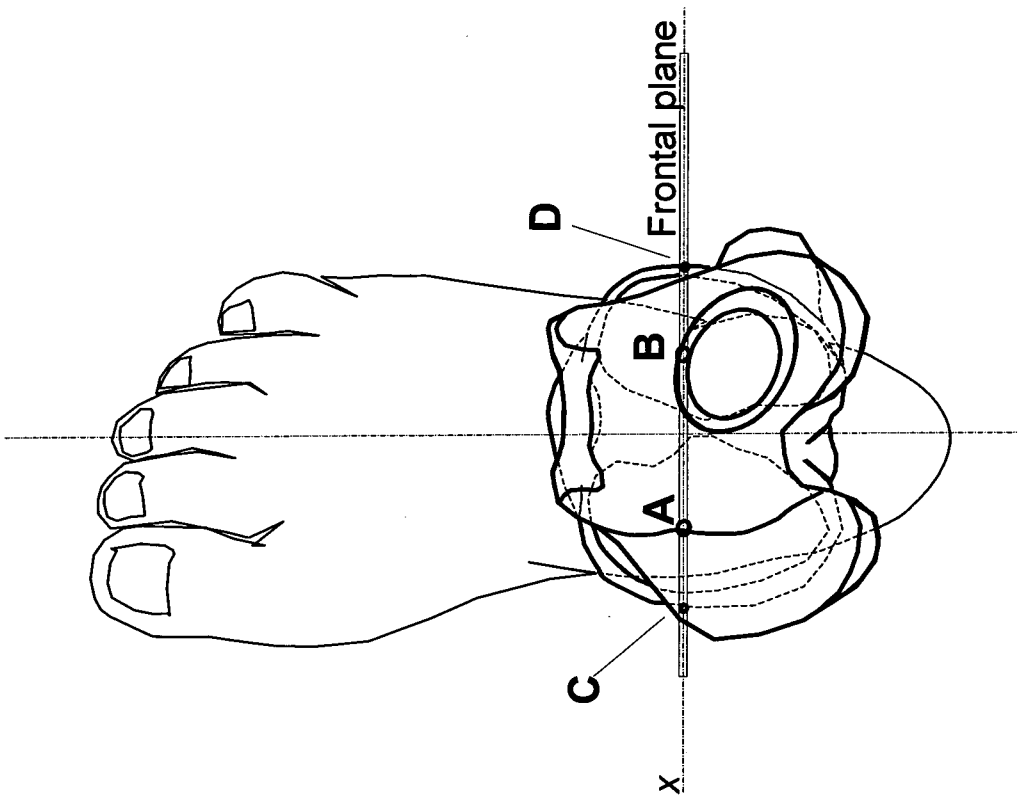

Frontal plane
D
B
A
C
x

Fig.6

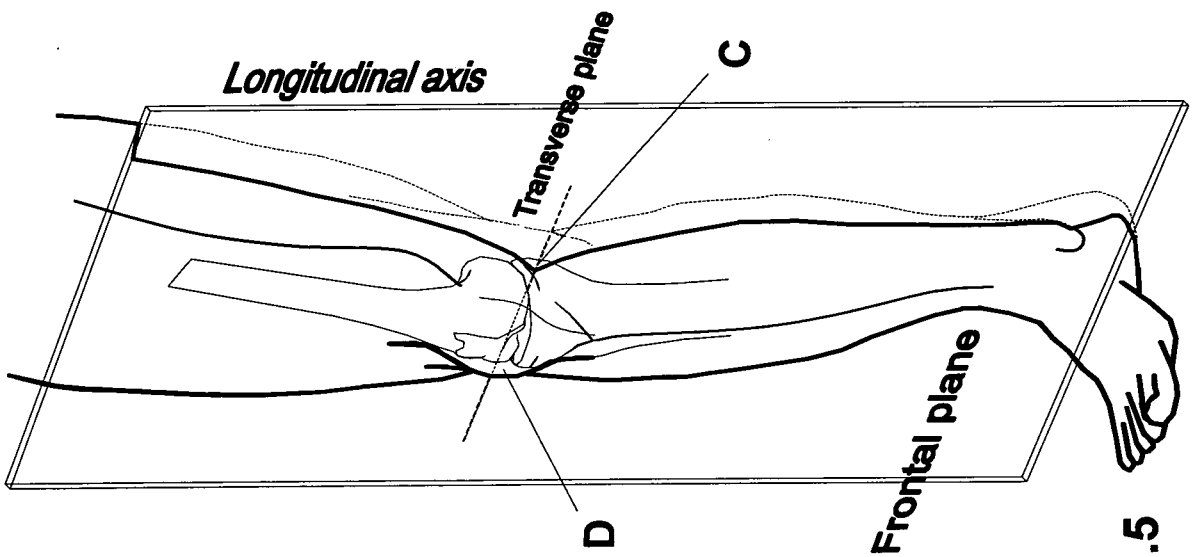

Longitudinal axis
Transverse plane
C
D
Frontal plane

Fig.5

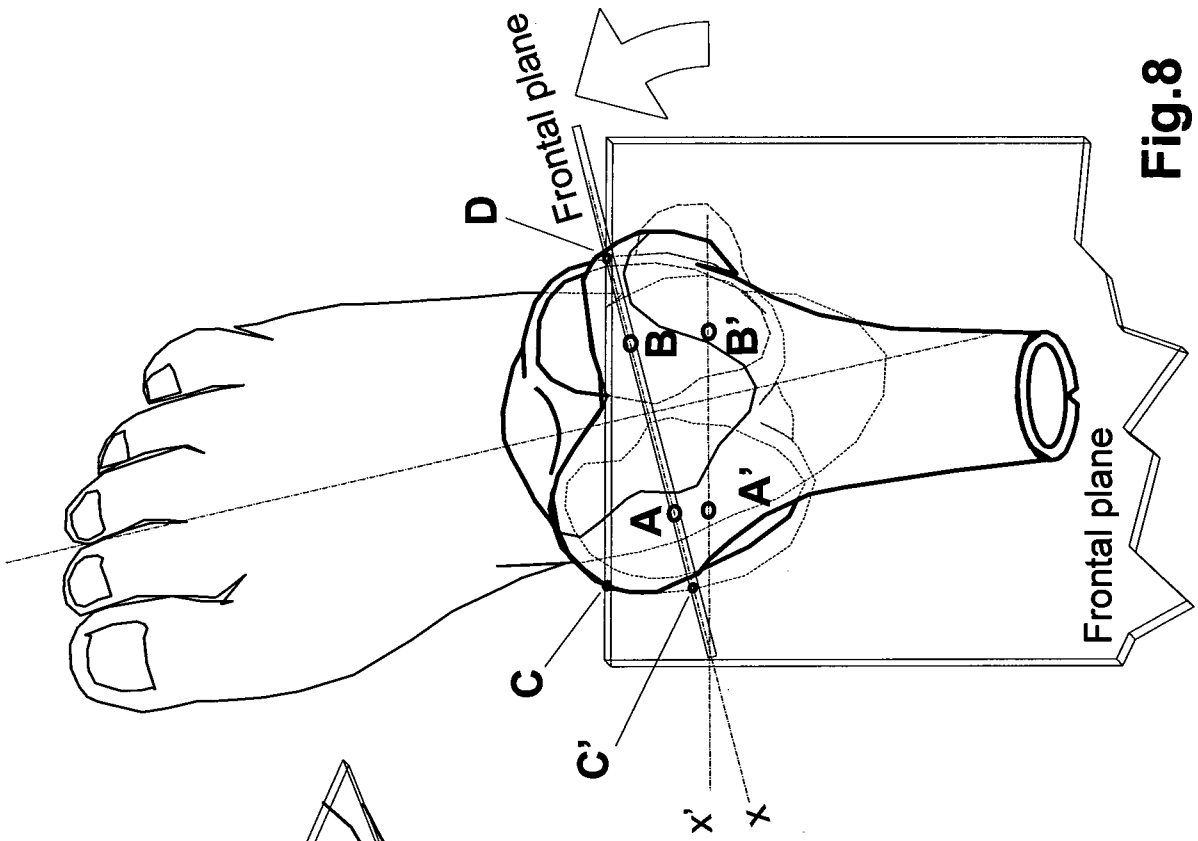


Fig.8

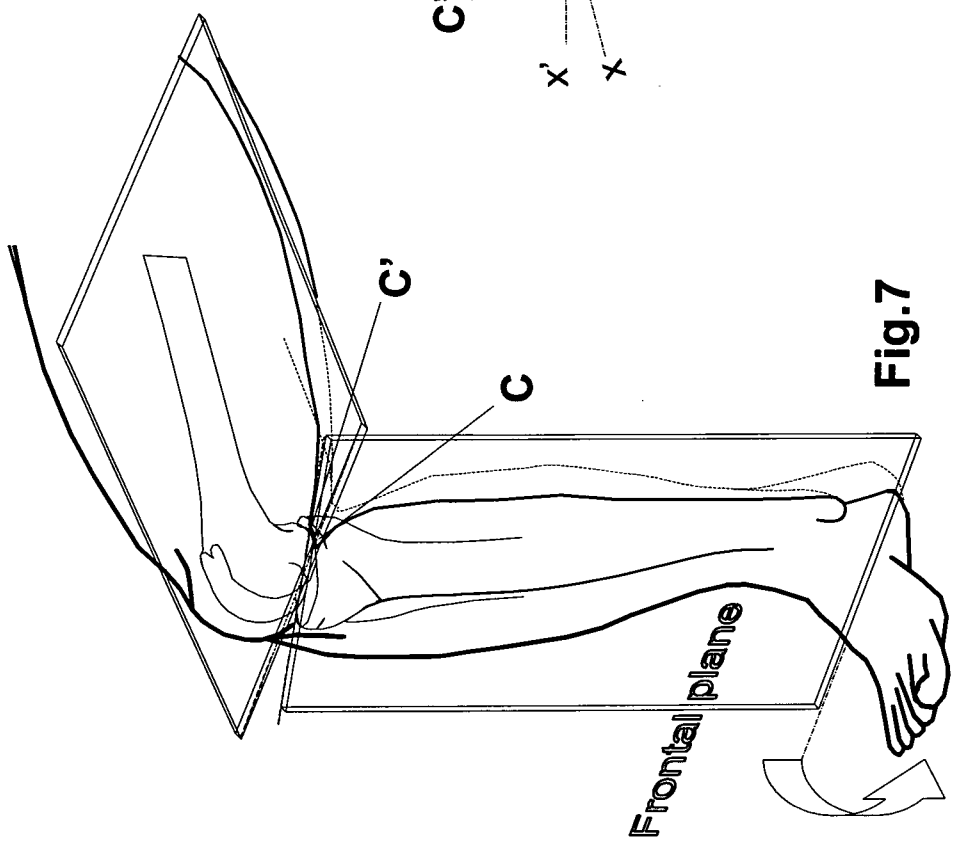


Fig.7

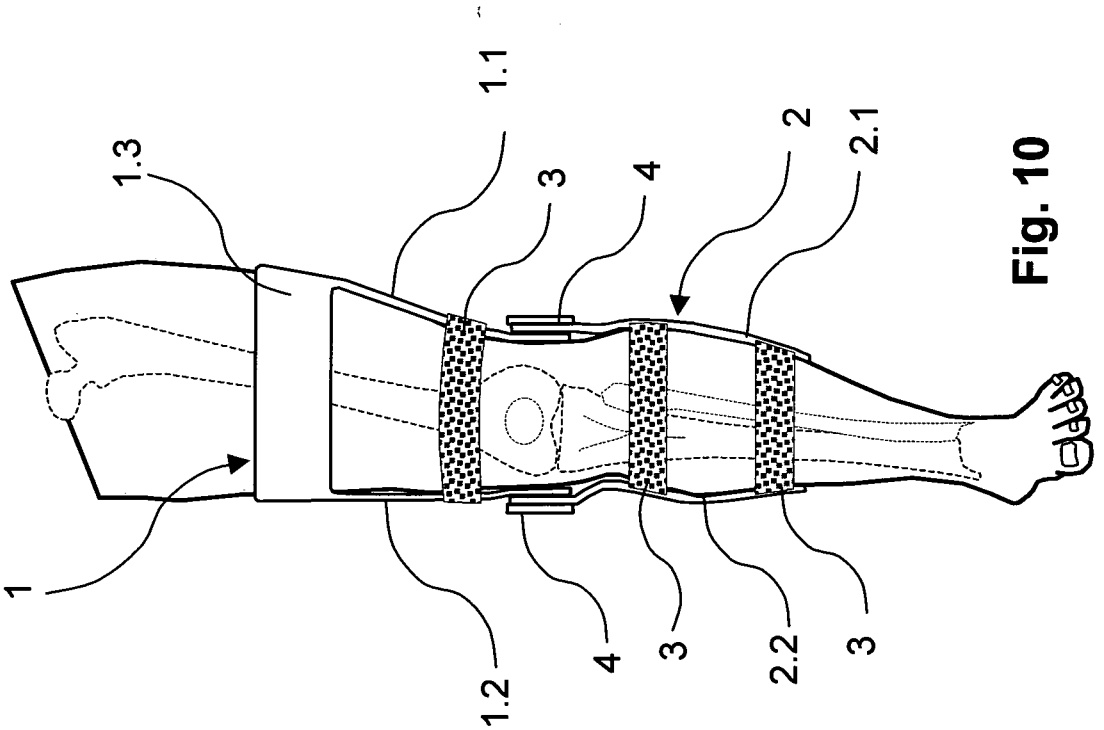


Fig. 10

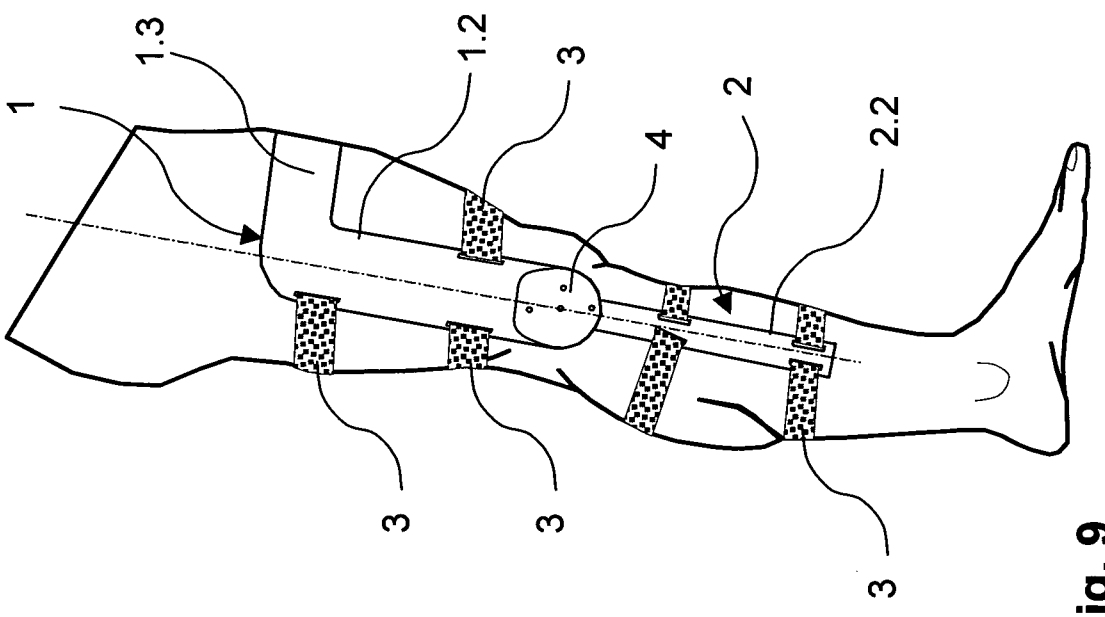


Fig. 9

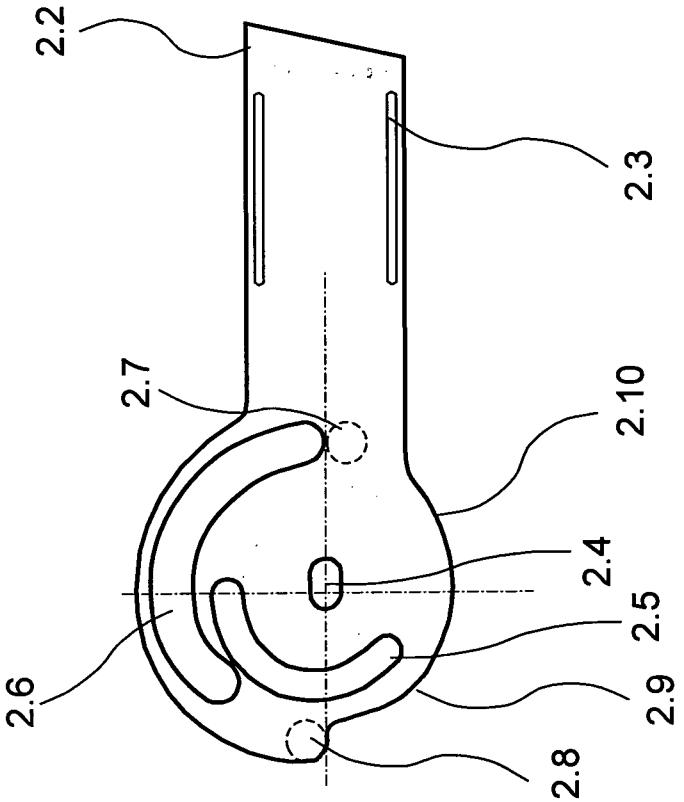


Fig. 12

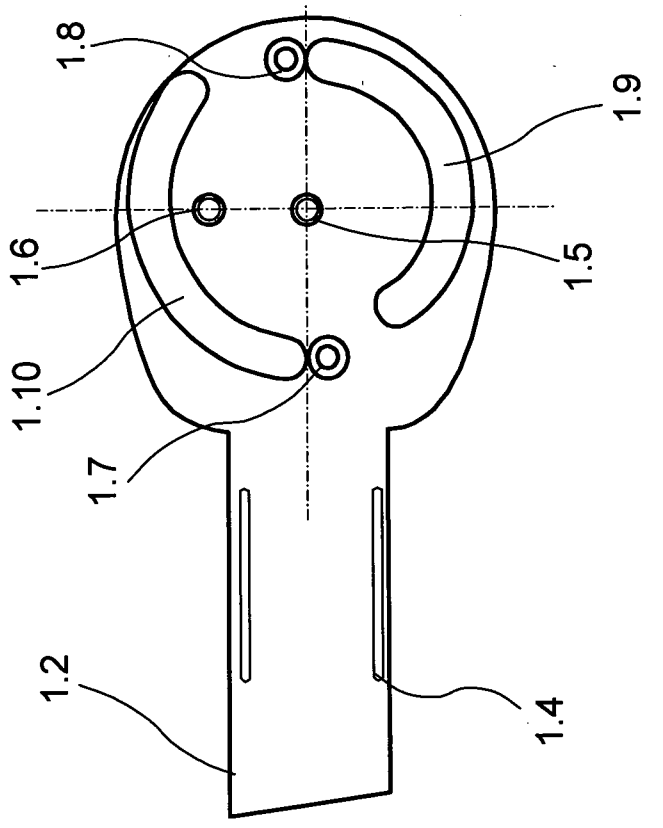


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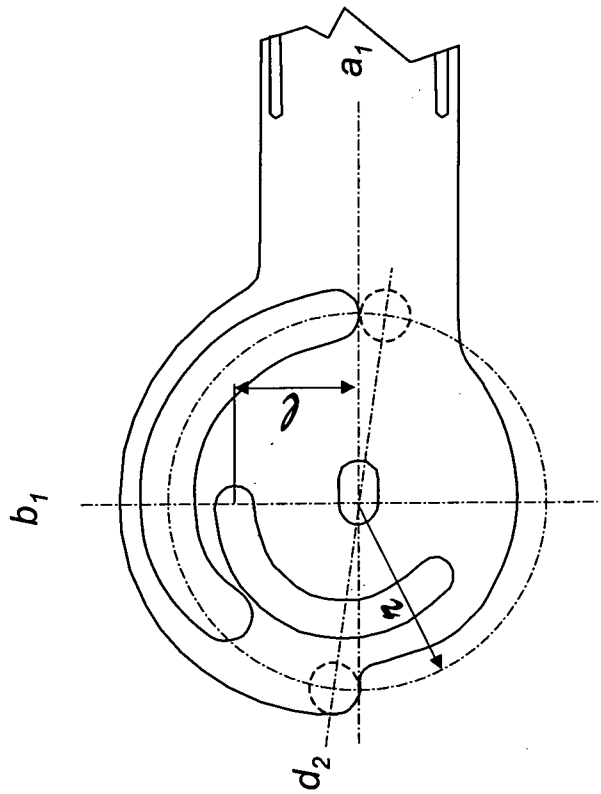


Fig. 14

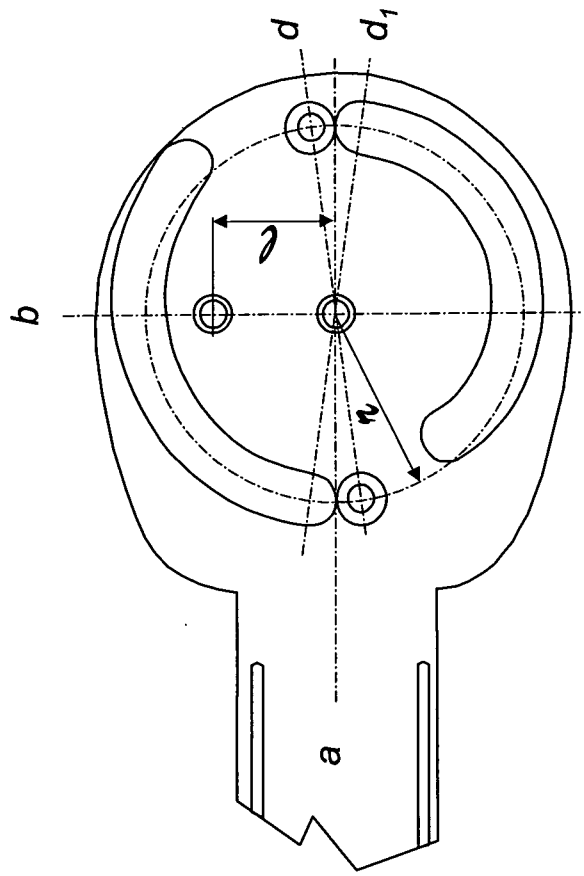


Fig. 13

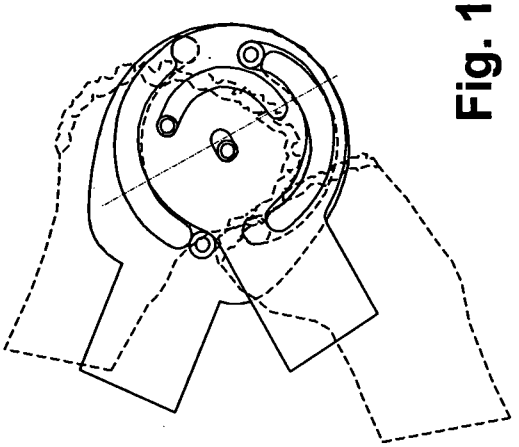


Fig. 18

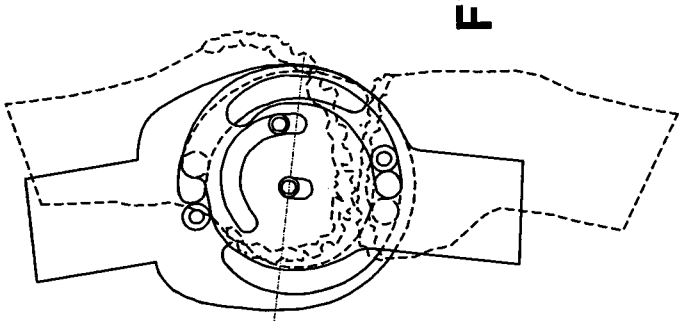


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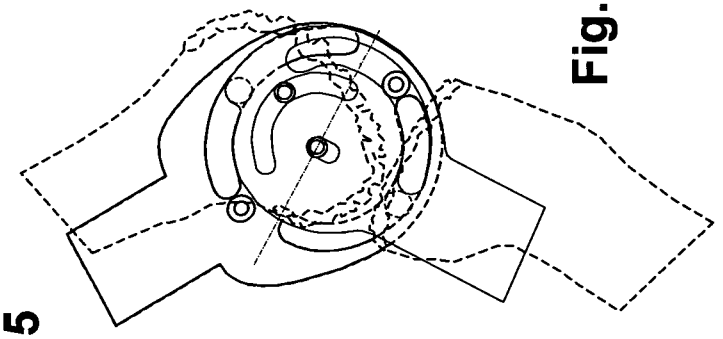


Fig. 17

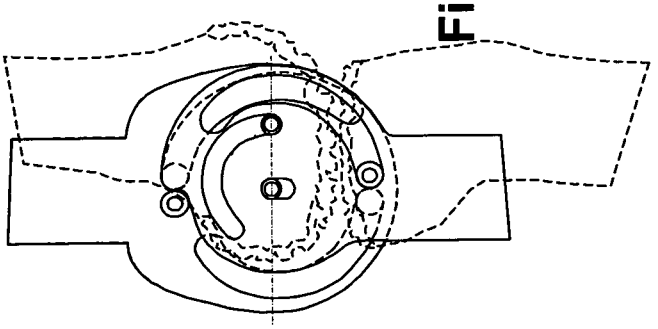


Fig. 15

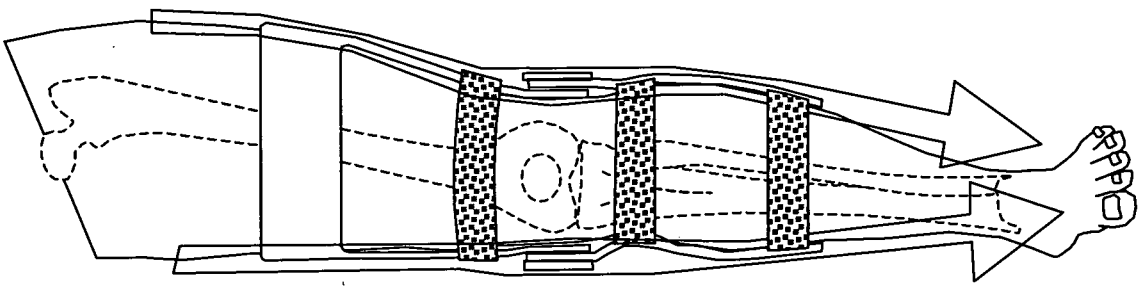


Fig. 19

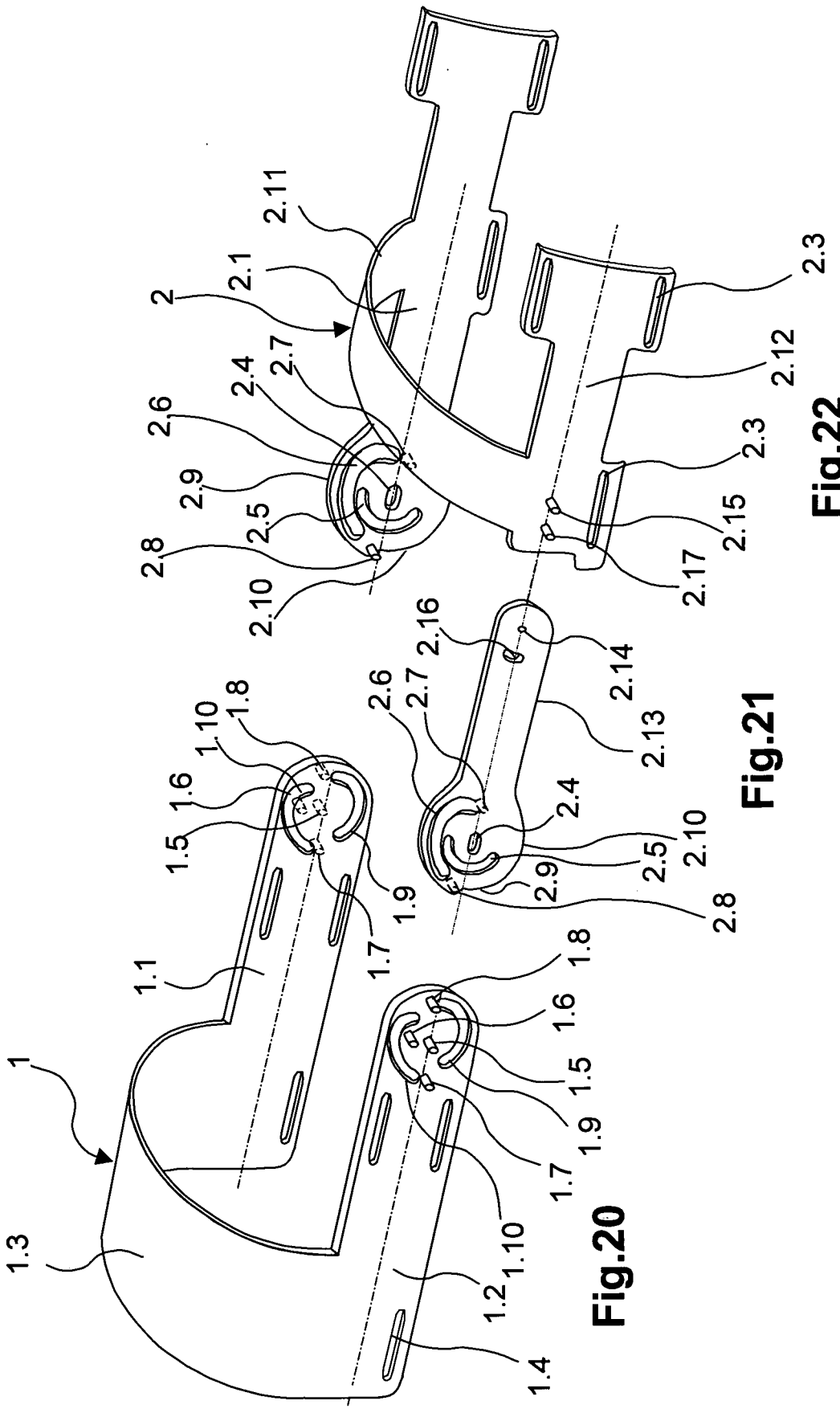


Fig.20

Fig.21

Fig.22

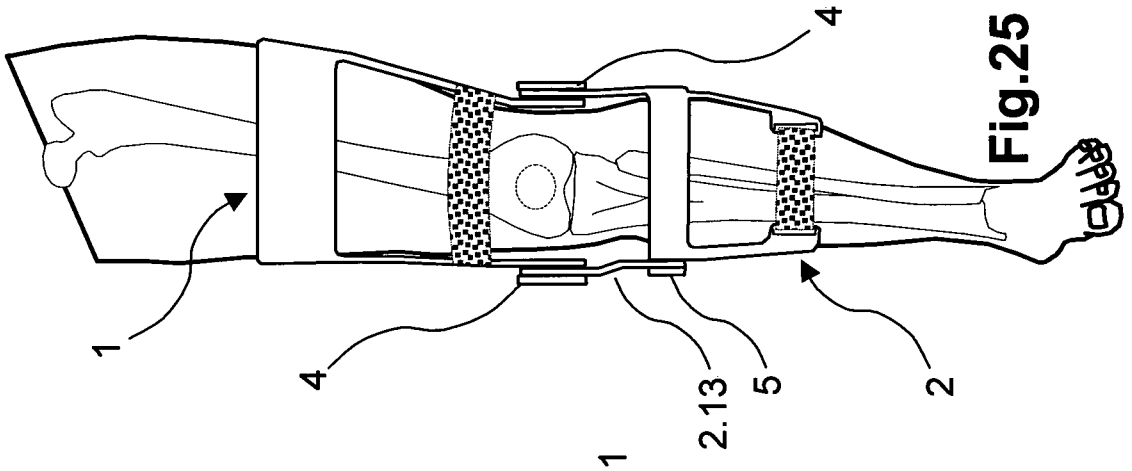


Fig.25

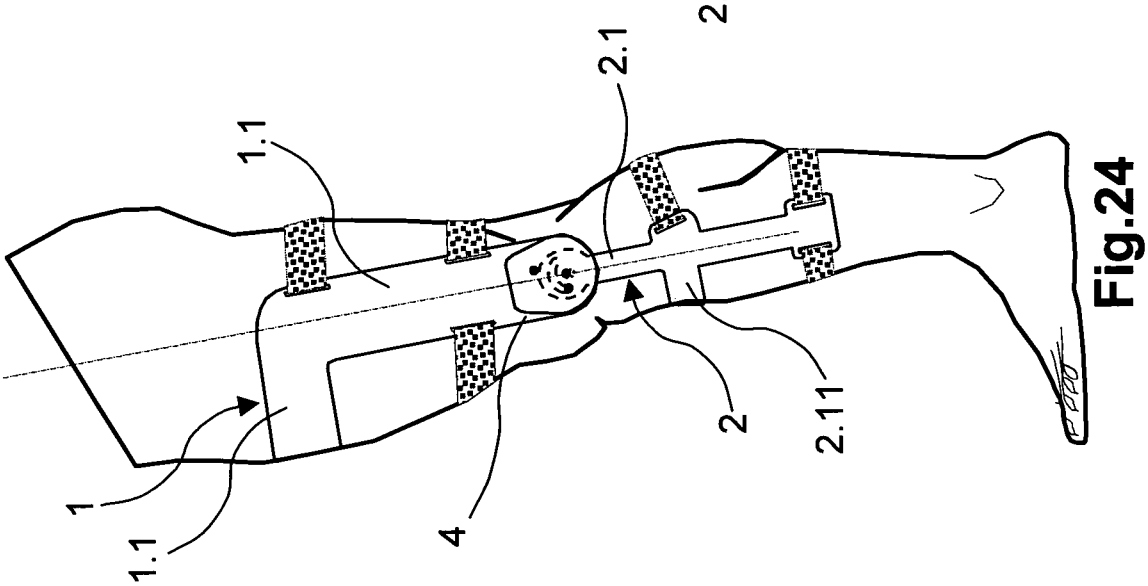


Fig.24

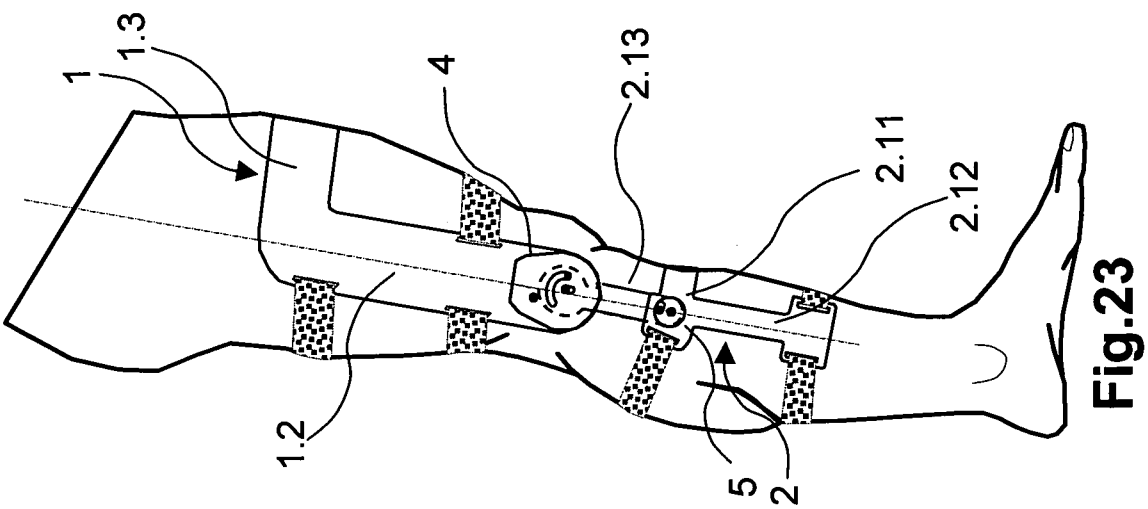


Fig.23

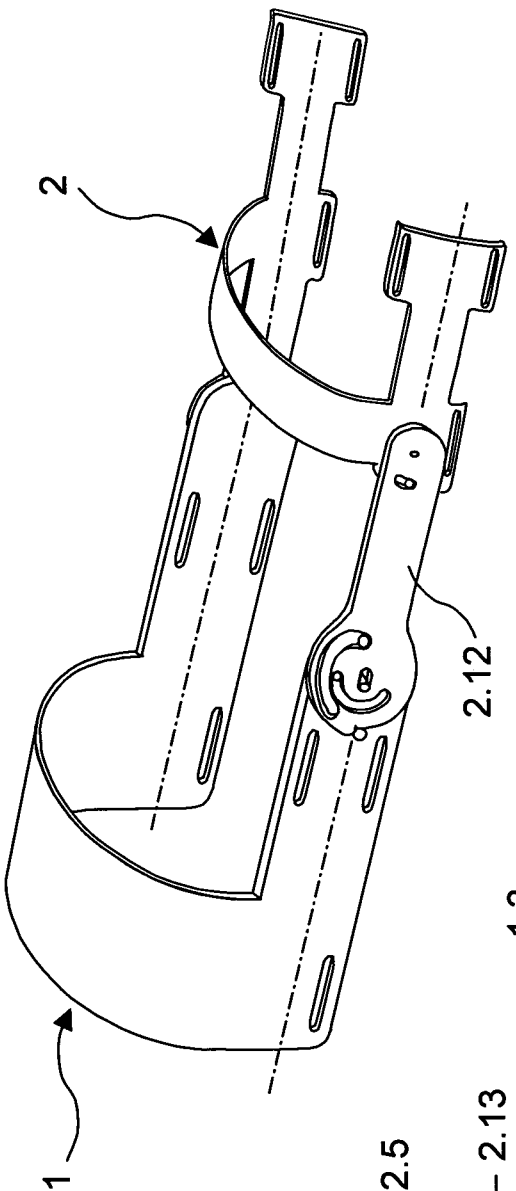


Fig.27

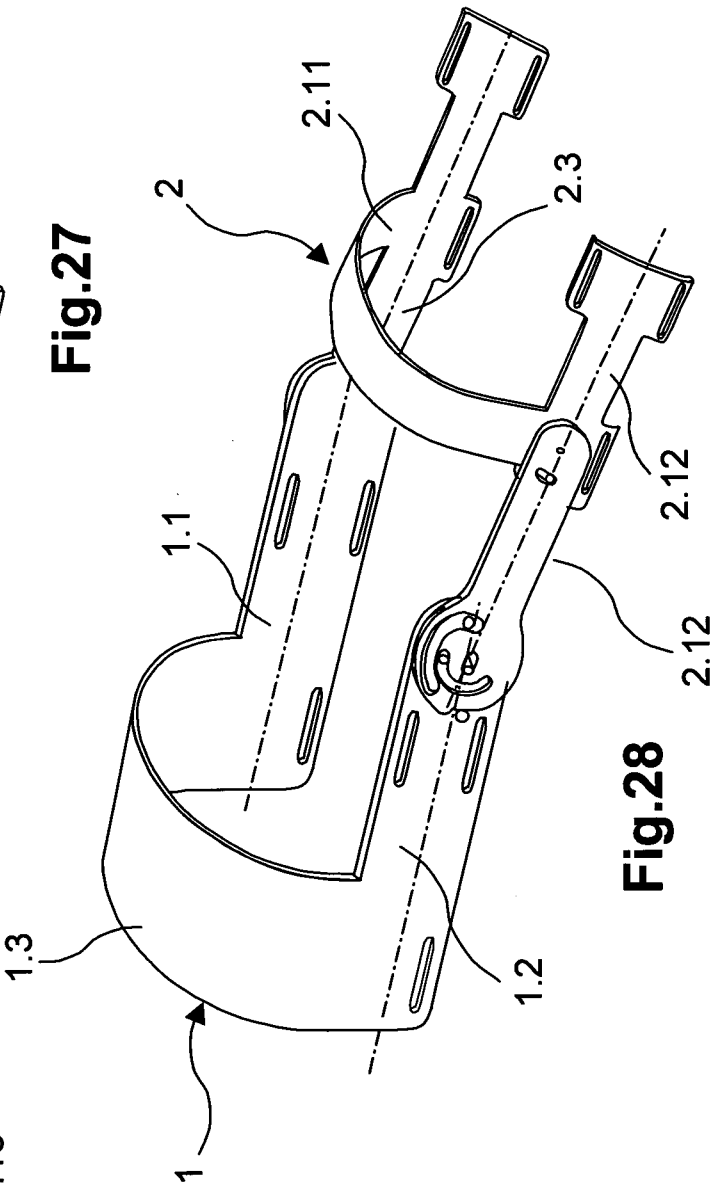


Fig.28

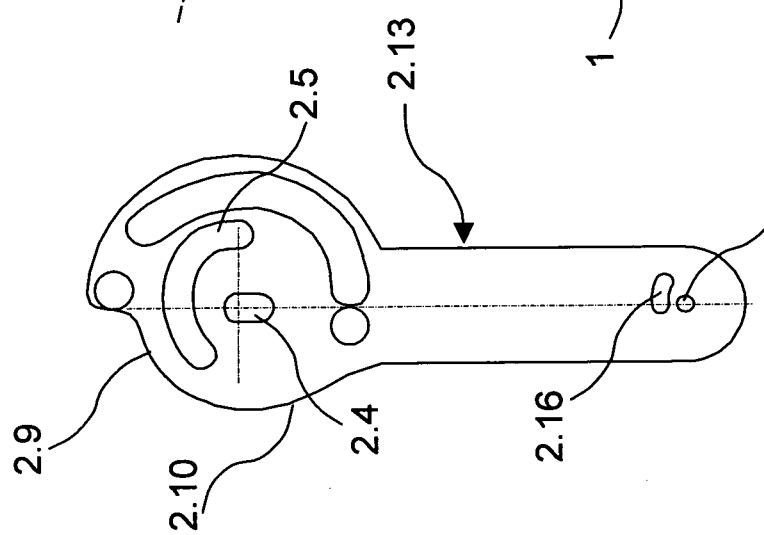


Fig.26

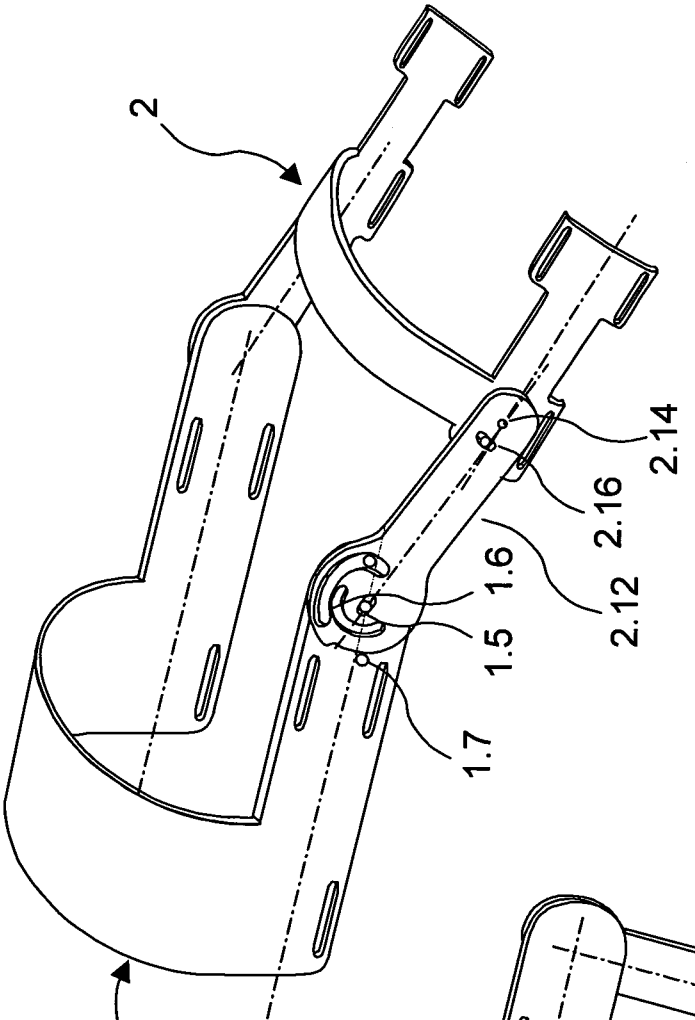


Fig.29

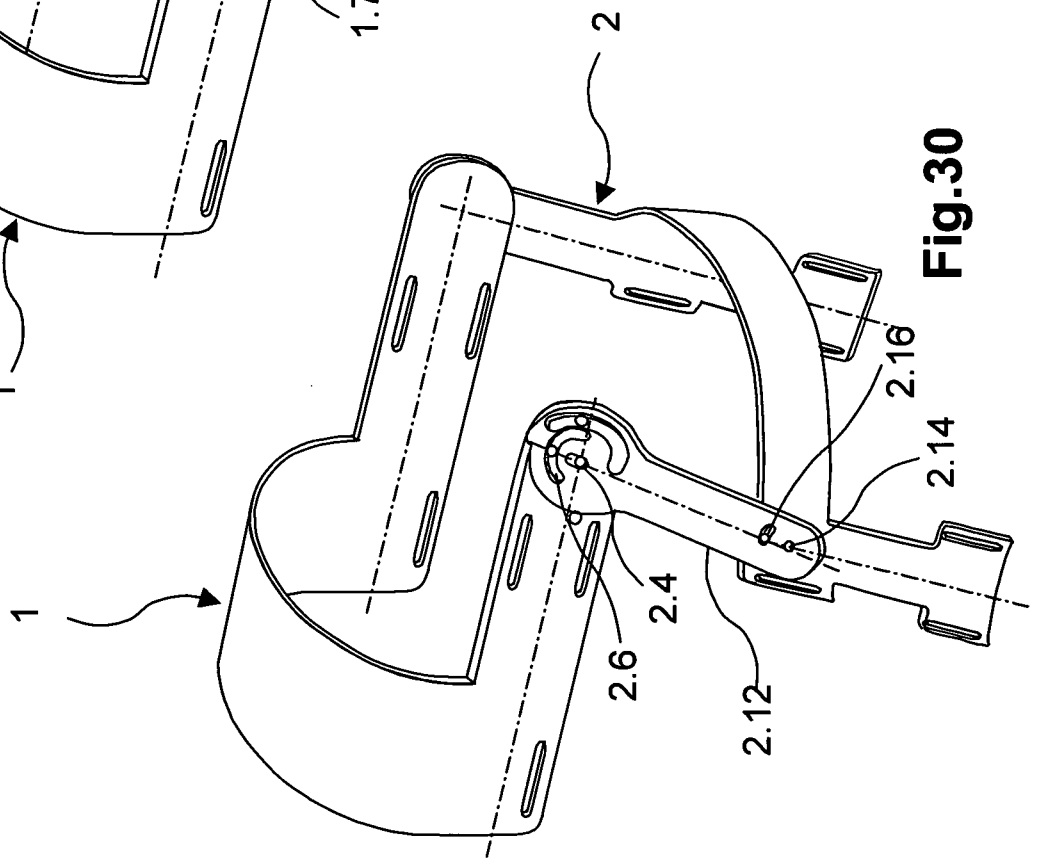


Fig.30

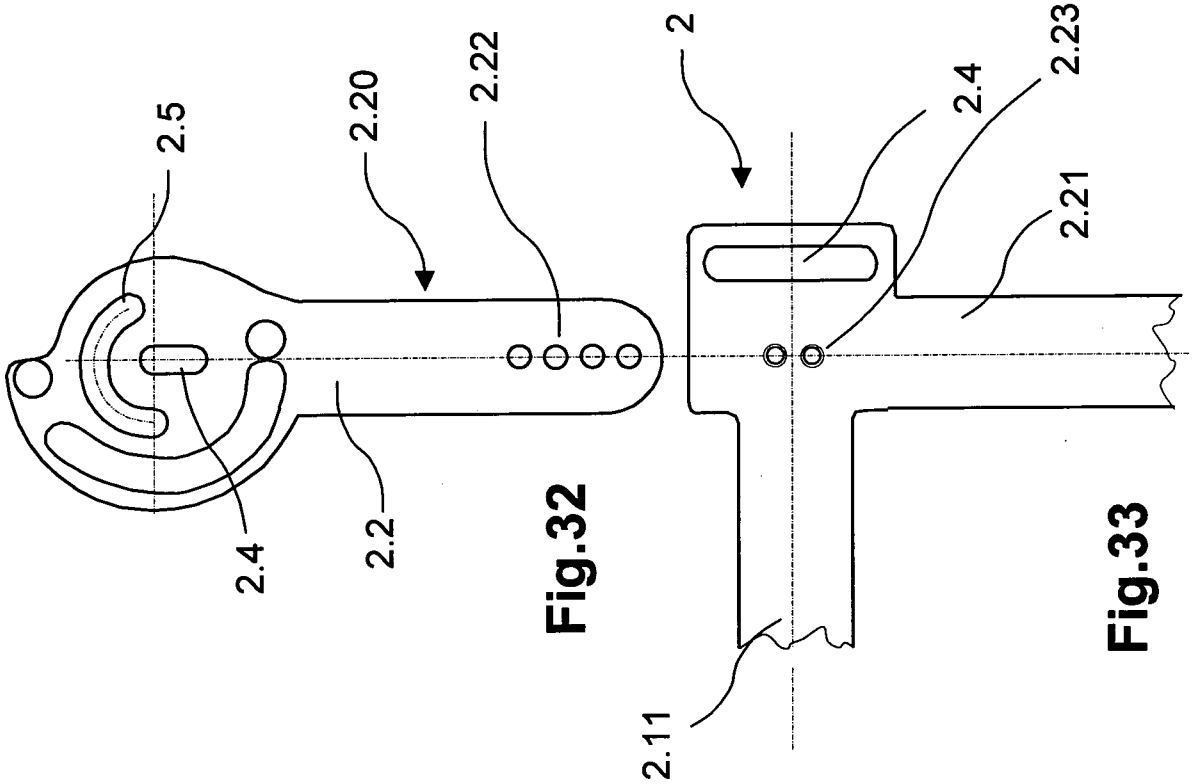


Fig.32

Fig.33

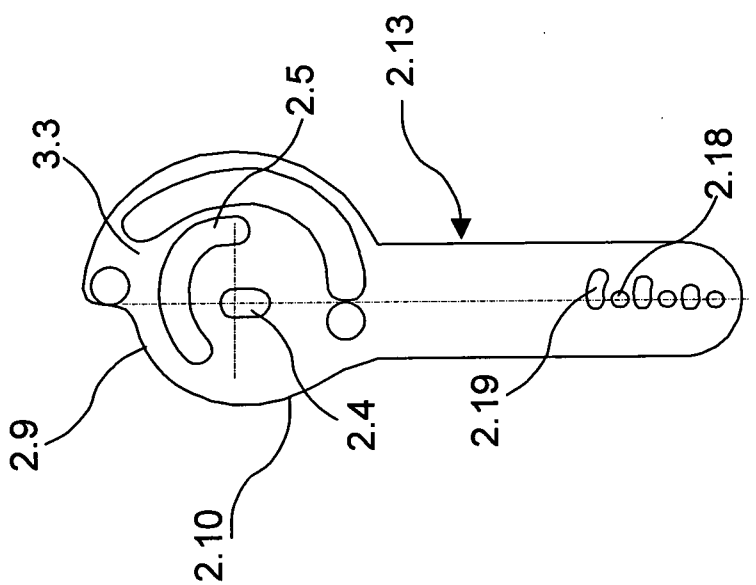


Fig.31

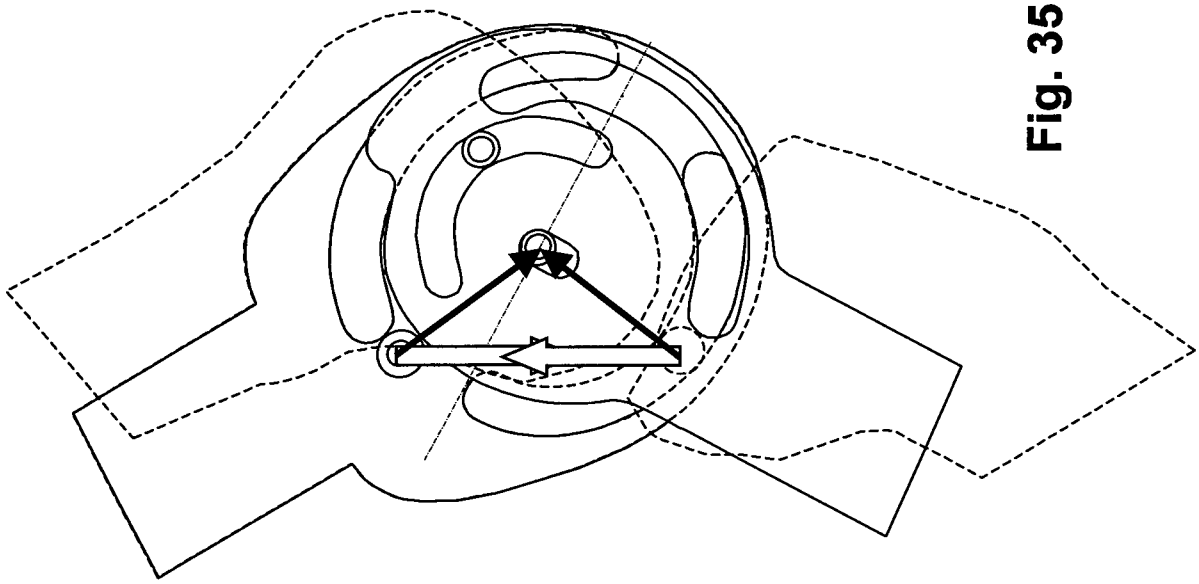


Fig. 35

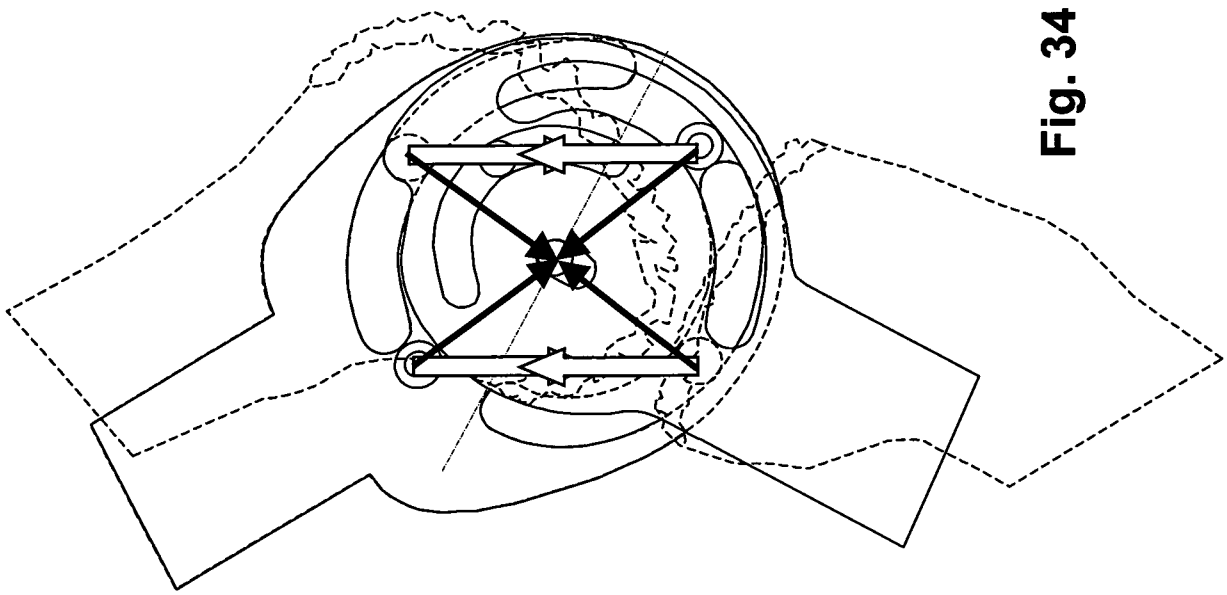


Fig. 34

INTERNATIONAL SEARCH REPORT

International application No
PCT/IT2009/000026

A. CLASSIFICATION OF SUBJECT MATTER
INV. A61F5/01

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 107 824 A (ROGERS MICHAEL M [US] ET AL) 28 April 1992 (1992-04-28) abstract; figures column 4, line 19 - column 10, line 54	1-10
A	DE 20 2006 005095 U1 (AEQUOS ENDOPROTHETIK GMBH [DE]) 1 June 2006 (2006-06-01) abstract; figures 1-4 paragraphs [0026] - [0028]	1-10
A	US 2005/148915 A1 (NATHANSON JEREMY J [US] ET AL) 7 July 2005 (2005-07-07) abstract; figures	1-10

-/--

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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"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

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"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

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Date of the actual completion of the international search	Date of mailing of the international search report
21 April 2009	08/05/2009

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Lager, Johan

INTERNATIONAL SEARCH REPORT

International application No
PCT/IT2009/000026

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	EP 0 361 405 A (TOWNSEND IND INC [US]) 4 April 1990 (1990-04-04) cited in the application abstract; figures	1-10
A	WO 92/15264 A (TOWNSEND JEFFREY H [US]; WILLIAMS ROBERT J [US]) 17 September 1992 (1992-09-17) cited in the application abstract; figures	1-10

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Information on patent family members

International application No
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