Lower leg prosthesis

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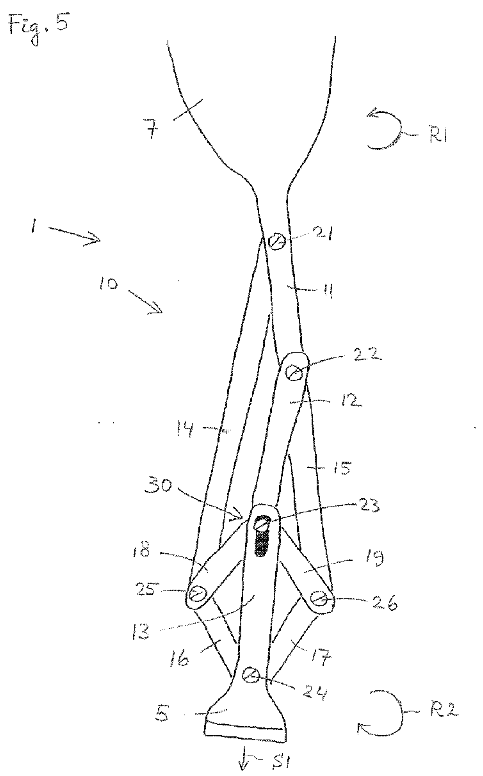
(54) Title: LOWER LEG PROSTHESIS



(57) Abstract: A lower leg prosthesis (1) comprises a distal end (for) having an artificial foot (5) and a proximal end (for) having a stump socket (7) for connection to a leg stump of an amputee. The prosthesis comprises a mechanism (10) which is arranged such that, in use condition of the prosthesis and in an upright position of said amputee with said artificial foot resting on a floor, in response to the amputee performing a rotative movement of said leg stump around its corresponding hip joint while keeping said artificial foot resting on the floor, said rotative movement at least occurring in the frontal plane of the amputee and in one rotation direction (R1) within the frontal plane, the prosthesis causes said artificial foot to rotate relative to the floor at least in the other, i.e. opposite, rotation direction (R2) within the frontal plane.

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Title: Lower leg prosthesis.

The invention relates to a lower leg prosthesis for an amputee who has at least one leg having a lower or upper leg stump, the prosthesis comprising a distal end forming an artificial foot, or the distal end being connectable to an artificial foot; and a proximal end forming a stump socket for connection to said leg stump, or the proximal end being connectable, optionally via an artificial knee, to a stump socket for connection to said leg stump. A use condition of the prosthesis is defined by the distal end actually being connected, if applicable, to said artificial foot, the proximal end actually being connected, if applicable, to said stump socket, and said stump socket actually being connected to said leg stump of said amputee.

Known prostheses for upper or lower leg amputees suffer from a number of drawbacks. Important drawbacks of the known prostheses are lack of balance and relatively high energy consumption during standing and walking. During walking with a known prosthesis this is for example visible from the typical gait pattern, showing compensatory trunk movements by the amputee as well as a wider gait to solve balance problems in the frontal plane of the amputee. The frontal plane is the sideways plane, as dinstinct from the sagittal plane (for-aft) of the amputee. Many improvements have been made on the design of prosthetic knees and feet, but only little attention has been given on the part between knee and foot, the lower leg, in order to improve lateral balance.

EP1340478A2 discloses a lower leg prosthesis of the type as initially identified hereinabove. This known prosthesis 1, shown in Figs. 1 through 7B of EP1340478A2, includes a foot portion 3, a leg mounting portion 4 and a parallel linkage 10 connecting these portions. The leg mounting portion 4 has a flat mounting plate 4a. The parallel linkage 10 includes one fixed link 11 and four expansible links 13. The fixed link 11 has an upper end thereof fixed to the mounting plate 4a and a lower end thereof connected to the foot portion 3 via a ball joint 12. Each of the four expansible links 13 has an upper end thereof connected to the mounting plate 4a via an upper ball joint 14a and a lower end thereof connected to the foot portion 3 via a lower ball joint 14b.

Due to these ball joints 12, 14a and 14b and the expansibility/compressibility of the links 13, the angle of the fixed link 11 with respect to the foot portion 3 can be changed in any desired direction. In short, there are at least three degrees of freedom for the fixed link 11 and, correspondingly, for the mounting plate 4a. Hence, due to this high degree of freedom, an amputee wearing the known prosthesis 1 on his or her living leg stump can tilt the prosthetic lower leg in any desired direction relative to a floor while keeping the artificial foot of the prosthesis 1 resting on the floor and without rotating the artificial foot relative to the floor on which it rests. Various such tilting positions of the prosthetic lower leg are shown in Figs. 5A, 5B, 6A, 6B, 7A and 7B of EP1340478A2. In all these positions the shown artificial foot 6 has not rotated relative to the floor on which it rests due to said high degree of freedom, which in fact is more or less similar to the high degree of freedom that occurs in case of a living leg having a living ankle joint and a living foot.

Due to said high degree of freedom, also this prosthesis 1 known from EP1340478A2 suffers from the abovementioned lateral balance problems, amongst others resulting into the abovementioned compensatory wider gait and compensatory trunk movements by the amputee during walking.

It is an object of the invention to provide a prosthetic solution according to which lateral balance of upper or lower leg amputees is substantially improved during standing and walking.

For that purpose, according to independent claim 1 of the invention, the lower leg prosthesis of the initially identified type is characterized by a mechanism which is arranged such that, in said use condition of the prosthesis and in an upright position of said amputee with said artificial foot resting on a floor, in response to the amputee performing a rotative movement of said leg stump around its corresponding hip joint while keeping said artificial foot resting on the floor, said rotative movement at least occurring in the frontal plane of the amputee and in one rotation direction within the frontal plane, the prosthesis causes said artificial foot to rotate relative to the floor at least in the other, i.e. opposite, rotation direction within the frontal plane.

Said rotative movement in the frontal plane of said leg stump around the hip joint is fully controllable from the hip muscles which are still available both in upper and lower leg amputees. The responsive, oppositely directed rotative movement of the artificial foot resting on the floor results in a lateral shifting of the center of pressure exerted by the artificial foot on the floor. It also results in a change of the ground reaction force considered to be acting on the (shifted) center of pressure, more in particular in a change of the horizontal component of that ground reaction force in the frontal plane. Controlling this horizontal ground reaction force is a dominant factor in controlling lateral balance of the amputee.

In other words, with a lower leg prosthesis according to the invention, the amputee is able to control the horizontal ground reaction force and thereby his or her lateral balance by performing a controlled movement with his or her still available hip muscles. Thus the invention provides improved lateral balance and reduced energy consumption during standing and walking. This results for example in an improved gait pattern requiring less compensatory trunk movements and allows a more narrow gait to solve balance problems in the frontal plane of the amputee.

The mechanism that realizes said rotating of the artificial foot responsive to said rotative movement of the leg stump may in principle be arranged in various ways, for example by means of various bar mechanisms and/or cylinder-piston configurations, whether or not motor driven and/or electronically controlled, or the like.

It is remarked that the abovementioned prosthesis known from EP1340478A2 does not comprise such a mechanism being arranged for causing such a responsive, oppositely directed rotative movement of the artificial foot relative to the floor on which it rests. Instead, in view of the aim to realize high degree of pivoting freedom at the artificial ankle joint, the prosthesis known from EP1340478A2 has deliberately been designed such that the artificial foot, in response to an amputee performing various tilting movements of the prosthetic lower leg, does not rotate at all relative to the floor on which it rests.

Specific embodiments of the invention are set forth in the appended dependent claims.

Preferably, said mechanism is furthermore arranged to prevent, during said rotative movement of said leg stump and said responsive rotating of said artificial foot still resting on the floor, the occurrence of loss of height of the hip joint relative to the floor, at least when said rotative movement of said leg stump around the hip joint, as seen in the frontal plane, is unidirectionally performed over at least five degrees in said one rotation direction starting from a position in which the leg stump is extending vertically under the hip joint, and at least when said rotative movement of said leg stump around the hip joint, as seen in the frontal plane, is unidirectionally performed over at least five degrees in said other, i.e. opposite, rotation direction starting from said position in which the leg stump is extending vertically under the hip joint. This prevention of the occurrence of loss of height of the hip joint relative to the floor takes away slight imbalances originating from slight losses of height that would occur due to said rotative movement of said leg stump. Instead of the mechanism being arranged for such prevention when such rotative movement is performed over the said at least five degrees in each of both rotation directions, it is more preferably if the mechanism is arranged for such prevention when such rotative movement is performed over at least ten degrees in each of both rotation directions, and it is yet more preferable if the mechanism is arranged for such prevention when such rotative movement is performed over at least twenty degrees in each of both rotation directions.

Also the means for realizing said prevention of the occurrence of loss of height of the hip joint relative to the floor may in principle be arranged in various ways, for example by means of various bar mechanisms and/or cylinder-piston configurations, whether or not motor driven and/or electronically controlled, or the like.

It is remarked that the abovementioned prosthesis known from EP1340478A2 does not comprise such a mechanism being arranged for said prevention of the occurrence of loss of height of the hip joint relative to the floor. Instead, for the prosthesis known from EP1340478A2 it is clear that in all tilting positions of the prosthetic lower leg, such as those shown in Figs. 5A, 5B, 6A, 6B, 7A and 7B of EP1340478A2, there definitely has occurred loss of height of the hip joint relative to the floor as compared to the upright position of the prosthetic lower leg shown in Figs. 3A and 3B of EP1340478A2.

In a preferable embodiment, the mechanism is a planar hinging bar mechanism having a hinging bar plane which in the use condition is parallel to the frontal plane of the amputee, the planar hinging bar mechanism comprising at least nine bars extending parallel to the hinging bar plane and hingingly interconnected with one another via at least six hinge axes extending perpendicular to the hinging bar plane, the at least nine bars comprising a first bar, a second bar, a third bar, a fourth bar, a fifth bar, a sixth bar, a seventh bar, an eighth bar and a ninth bar, the at least six hinge axes comprising a first hinge axis, a second hinge axis, a third hinge axis, a fourth hinge axis, a fifth hinge axis and a sixth hinge axis;

wherein, as seen in said hinging bar plane, in a zero position of the planar hinging bar mechanism the first hinge axis, the second hinge axis, the third hinge axis and the fourth hinge axis are lying spaced from one another on a straight line, indicated as zero line, with the second hinge axis lying between the first hinge axis and the third hinge axis and with the third hinge axis lying between the second hinge axis and the fourth hinge axis, whereas the fifth hinge axis is lying on one side of the zero line at orthogonal lateral distance from a portion of the zero line between the third hinge axis and the fourth hinge axis, and the sixth hinge axis is lying on the other, opposite side of the zero line at orthogonal lateral distance from said portion of the zero line;

wherein the at least nine bars being hingingly interconnected with one another via the at least six hinge axes is realized in that the first bar is hingingly connected to the first hinge axis and to the second hinge axis, the second bar is hingingly connected to the second hinge axis and to the third hinge axis, the third bar is hingingly connected to the third hinge axis and to the fourth hinge axis, the fourth bar is hingingly connected to the first hinge axis and to the fifth hinge axis, the fifth bar is hingingly connected to the first hinge axis and to the sixth hinge axis, the sixth bar is hingingly connected to the fifth hinge axis and to the fourth hinge axis, the seventh bar is hingingly connected to the sixth hinge axis and to the fourth hinge axis, the eighth bar is hingingly connected to the fifth hinge axis and to the third hinge axis, and the ninth bar is hingingly connected to the sixth hinge axis and to the third hinge axis;

wherein all said hinging connections between said bars and said hinge axes are non-sliding hinging connections, i.e. not allowing sliding, in the hinging bar plane, of such a bar relative to its corresponding hinge axes, except for the fact that the connection of the third bar to only one of the third hinge axis and the fourth hinge axis is a slidable connection allowing sliding of the third bar relative to said only one hinge axis back and forth in a sliding direction extending, in the hinging bar plane, through the third hinge axis and the fourth hinge axis; and

wherein ends of the first bar and the third bar, respectively, are forming said proximal end and said distal end of the prosthesis, respectively, or vice versa.

With such a planar hinging bar mechanism said rotative movement of said leg stump while keeping said artificial foot resting on the floor causes the hinging bar mechanism to hinge, during which hinging the changing angle between the first bar and the third bar causes said rotating of said artificial foot, still resting on the floor, responsive to said rotative movement of said leg stump. Furthermore, during said hinging of the hinging bar mechanism, the distance between the third hinge axis and the fourth hinge axis automatically adapts, which is allowed by said slidable connection of the third bar, so as to prevent the occurrence of loss of height of the hip joint relative to the floor.

The planar hinging bar mechanism provides the advantages that it is reliable, compact, lightweight, as well as easy to manufacture and repair. It does not require to be motor driven or electronically controlled.

Preferably, in said zero position and as seen in said hinging bar plane, the positions of the fifth hinge axis and the sixth hinge axis are mutual mirrow image positions relative to the zero line. Such a symmetry promotes that the extent of said responsive counter-rotation of the artificial foot is similar for both directions of rotation of the leg stump around the hip joint in the frontal plane.

Preferably, as seen in the hinging bar plane, the distance between the fourth hinge axis and the fifth hinge axis is larger than the distance between the fifth hinge axis and the third hinge axis. Such a property promotes an effective and substantial responsive rotation of the foot.

In a preferable embodiment the first bar and/or the second bar and/or the third bar and/or the fourth bar and/or the fifth bar and/or the sixth bar and/or the seventh bar and/or the eighth bar and/or the ninth bar is, or are each, length adjustable into different lockable lengths. Such adjustability allows for easily adapting the characteristics of the prosthesis in dependence of an amputee's wishes and/or needs. It also enables the manufacture of more or less standardized prostheses which may easily be made individually applicable to various dimensions of amputees, leg stumps, artificial feet or artificial knees.

These and other aspects of the invention will be apparent from and elucidated with reference to the embodiments described hereinafter by way of non-limiting examples only and with reference to the schematic figures in the enclosed drawing.

Fig. 1 shows, in highly schematical form, an example of an embodiment of a prosthesis according to the invention in its use condition with an amputee standing on a floor, the figure being shown in front view, i.e. in the frontal plane of the amputee.

Fig. 2 shows the example of Fig. 1 once again, however in a condition in which the amputee has performed, relative to the condition shown in Fig. 1, a rotative movement of the leg stump around its corresponding hip joint while keeping the artificial foot resting on the floor, said rotative movement occurring in the shown frontal plane of the amputee.

Fig. 3 shows, in a front view similar to that of Fig. 1, an example of a more detailed embodiment of a prosthesis according to the invention, which embodiment comprises a planar hinging bar mechanism in its zero position.

Fig. 4 shows the example of Fig. 3 in side view, i.e. in the sagittal plane of the amputee.

Fig. 5 shows the example of Fig. 3 once again, however in a condition in which the amputee has performed, relative to the condition shown in Fig. 3, a rotative movement of the leg stump similar to the rotative movement as performed in the embodiment of Fig. 2.

Fig. 6 shows, in highly schematical form, hinge axes and center lines of bars of the planar hinging bar mechanism of Fig. 3, wherein the full lines indicate center line positions of the bars as shown in the condition of Figs. 3 and 4, whereas the broken lines indicate center line positions of the bars as shown in Fig. 5.

Reference is first made to the embodiment shown in Figs. 1 and 2. The upper parts of Figs. 1 and 2 show amputee 2 standing in upright position with the feet of both legs resting on floor 8. The amputee 2 has a left leg (in the upper parts of Figs. 1 and 2 shown on the right hand side) having a lower leg stump 3 below the amputee's natural knee 50. The highly schematically shown lower leg prosthesis 101 is in its use condition, in which the distal end 4 is forming artificial foot 5, the proximal end 6 is forming a stump socket (the stump socket is not shown in detail in the highly schematical Figs. 1 and 2), and the stump socket is connected to said leg stump 3. The other, right leg (in the upper parts of Figs. 1 and 2 shown on the left hand side) of the amputee is completely natural, i.e. it does not comprise a leg prosthesis.

The prosthesis 101 comprises a mechanism 110 which is arranged such that, in response to the amputee 2 performing a rotative movement of the leg stump 3 around his or her hip joint 9 of the left leg while keeping the artificial foot 5 resting on the floor 8, said rotative movement at least occurring in the frontal plane of the amputee 2 and in one rotation direction within the frontal plane, the prosthesis 101 causes said artificial foot 5 to rotate relative to the floor 8 at least in the other, i.e. opposite, rotation direction within the frontal plane.

It is remarked that the mechanism 110 has only been shown in highly schematically form in Figs. 1 and 2. The reason is that the inventive functions of the mechanism 110 may in principle be realized by means of various structural components, many of which will be readily apparent for the skilled person, once the functions of the mechanism have been invented. However, very special and nonobvious ways of realizing the functions of the mechanism in structural terms will be discussed later on with reference to further specific embodiments of the invention as illustrated with reference to Figures 3-6.

In the upper part of Fig. 1 no such rotative movement has yet been carried out, the mechanism 110 is in its "zero position". In the zero position the artificial foot 5 is resting on the floor 8 with the bottom face of its sole substantially in parallel contact with the floor 8.

The lower part of Fig. 1 shows the artificial foot 5 in this condition in an enlarged view. In the lower part of Fig. 1 there is shown the ground reaction force 41 in the frontal plane considered to be acting on the center of pressure 40. This ground reaction force 41 is substantially vertically directed, it has substantially no horizontal component.

Fig. 2 shows the situation after such rotative movement has indeed been carried out. Therefore, in the upper part of Fig. 2 the mechanism 110 is not in its zero position anymore. In this position the artificial foot 5 is still resting on the floor 8. Starting off from the zero position in Fig. 1, in Fig. 2 a rotative movement of the leg stump 3 around the hip joint 9 has been carried out in the anti-clockwise rotation direction, indicated in Figs. 1 and 2 as R1, within the frontal plane. Responsive to that anti-clockwise rotation R1 of the leg stump 3, the prosthesis 101 has caused artificial foot 5 to rotate relative to the floor 8 in clockwise direction, indicated in Figs. 1 and 2 as R2, within the frontal plane. It is remarked that, in the example of Figs. 1 and 2, the amputee has kept the lateral position (within the frontal plane) of the hip joint 9 relative to the artificial foot 5 unaltered during the performing of the rotative movement of the leg stump 3 around the hip joint 9. This can be seen in the upper parts of Figs. 1 and 2.

The lower part of Fig. 2 shows the artificial foot 5 in the rotated condition in an enlarged view. In the lower part of Fig. 2 there is shown the ground reaction force 43 in the frontal plane considered to be acting on the shifted center of pressure 42. Note, that the position of the center of pressure 42 in Fig. 2 has shifted relative to the position of the center of pressure 40 in Fig. 1 in a horizontal direction that faces away from the other, natural leg. Contrary to the ground reaction force 41 in Fig. 1, the ground reaction force 43 in Fig. 2 indeed has a substantial horizontal component. Note, that in the lower part of Fig. 2 the sole of foot 5 has been shown in an elastically deformed condition due to the rotation of the foot 5 in the clockwise direction R2.

Conversely, responsive to a clockwise rotation of the leg stump 3, the prosthesis 101 will cause artificial foot 5 to rotate in anti-clockwise direction. In that case the center of pressure will shift relative to the position of the center of pressure 40 in Fig. 1 in a horizontal direction that faces towards the other, natural leg.

Hence, despite the fact that the amputee 2 lacks neuromechanical control in the lower leg due to a missing natural lower leg, the amputee 2 is able to control, thanks to the lower leg prosthesis 101, the horizontal ground reaction force and thereby his or her lateral balance by performing a controlled movement with his or her still available hip muscles. By varying the extent and/or direction of the controlled movements with the hip muscles, the amputee is able to accurately control his or her lateral balance in a very natural way.

The mechanism 110 may furthermore be arranged to prevent, during certain rotative movements of the leg stump 3 and the responsive rotating of the artificial foot 5 still resting on the floor, the occurrence of loss of height of the hip joint 9 relative to the floor 8, i.e. at least when such rotative movement of said leg stump around the hip joint, as seen in the frontal plane, is unidirectionally performed over at least five degrees in said one rotation direction starting from a position in which the leg stump is extending vertically under the hip joint, and at least when such rotative movement of said leg stump around the hip joint, as seen in the frontal plane, is unidirectionally performed over at least five degrees in said other, i.e. opposite, rotation direction starting from said position in which the leg stump is extending vertically under the hip joint. Note that Fig. 1 shows the said position in which the leg stump 3 is extending vertically under the hip joint 9. This prevention of the occurrence of loss of height of the hip joint 9 relative to the floor 8 takes away slight imbalances originating from slight losses of height that would occur due to said rotative movement of said leg stump. It is remarked that also this inventive function of the mechanism 110 may in principle be realized by means of various structural components, many of which will be readily apparent for the skilled person, once this function of the mechanism has been invented. For this reason, Figs. 1 and 2 do not specifically show such structural components. However, very special and nonobvious ways of realizing this function of the mechanism in structural terms will be discussed below with reference to further specific embodiments of the invention as illustrated with reference to Figures 3-6.

Reference is now made to the prosthesis 1 shown in Figs. 3-6. This prosthesis 1 and its planar hinging bar mechanism 10 may in fact be seen as a more detailed embodiment of prosthesis 101 and its mechanism 110, respectively, of Figs. 1 and 2. With the prosthesis 1 and its mechanism 10 there can be performed at least the same operational functions as the more generally described operational functions that can be performed with the prosthesis 101 and its mechanism 110 of Figs. 1 and 2. For that reason, some parts and aspects of the prosthesis 1 of Figs. 3-6 have been indicated with the same reference signs as used for corresponding parts and aspects of the prosthesis 101 of Figs. 1 and 2. For simplicity, the floor 8 has been omitted in Figs. 3-6 and the hip joint 9 has been indicated only in Fig. 6.

The planar hinging bar mechanism 10 comprises first bar 11, second bar 12, third bar 13, fourth bar 14, fifth bar 15, sixth bar 16, seventh bar 17, eighth bar 18 and ninth bar 19, first hinge axis 21, second hinge axis 22, third hinge axis 23, fourth hinge axis 24, fifth hinge axis 25 and sixth hinge axis 26.

The first bar 11 is hingingly connected to the first hinge axis 21 and to the second hinge axis 22, the second bar 12 is hingingly connected to the second hinge axis 22 and to the third hinge axis 23, the third bar 13 is hingingly connected to the third hinge axis 23 and to the fourth hinge axis 24, the fourth bar 14 is hingingly connected to the first hinge axis 21 and to the fifth hinge axis 25, the fifth bar 15 is hingingly connected to the first hinge axis 21 and to the sixth hinge axis 26, the sixth bar 16 is hingingly connected to the fifth hinge axis 25 and to the fourth hinge axis 24, the seventh bar 17 is hingingly connected to the sixth hinge axis 26 and to the fourth hinge axis 24, the eighth bar 18 is hingingly connected to the fifth hinge axis 25 and to the third hinge axis 23, and the ninth bar 19 is hingingly connected to the sixth hinge axis 26 and to the third hinge axis 23.

The connection of the third bar 13 to the third hinge axis 23 is a slidable connection 30 allowing sliding of the third bar 13 relative to the third hinge axis 23 back and forth in the sliding direction S1 extending, in the hinging bar plane, through the third hinge axis 23 and the fourth hinge axis 24. In the shown example, the slidable connection 30 is realized by means of a slot in the third bar 13, the slot being indicated in a black-filled manner in Figs. 3 and 5. The third hinge axis 23 is slidable in said slot. Alternatively, i.e. instead of arranging the mechanism 10 such that the connection of the third bar 13 to the third hinge axis 23 is such a slidable connection, the mechanism 10 may also be arranged such that the connection of the third bar 13 to the fourth hinge axis 24 is such a slidable connection allowing sliding of the third bar 13 relative to the fourth hinge axis 24 back and forth in said sliding direction S1. In that case the fourth hinge axis 24 may be slidable in such a slot in the third bar 13.

In the shown example, an end of the first bar 11 is in the form of the stump socket 7 and therefore is forming the proximal end 6 of the prosthesis 1, whereas an end of the third bar 13 is in the form of the artificial foot 5 and therefore is forming the distal end 4 of the prosthesis 1. As an alternative embodiment, the mechanism 10 may be arranged upside-down relative to the shown example in the sense that an end of the first bar 11 is in the form of the artificial foot 5 and therefore is forming the distal end 4 of the prosthesis 1, whereas an end of the third bar 13 is in the form of the stump socket 7 and therefore is forming the proximal end 6 of the prosthesis 1.

With such a planar hinging bar mechanism 10 a rotative movement R1 of the leg stump 3 around the hip joint 9 while keeping the artificial foot 5 resting on the floor 8 causes the hinging bar mechanism 10 to hinge, during which hinging the changing angle between the first bar 11 and the third bar 13 causes rotative movement R2 of the artificial foot 5 relative to the floor 8, the artificial foot 5 still resting on the floor 8, responsive to the rotative movement R1 of the leg stump 3. As indicated in Figs. 3, 5 and 6, the rotative movement R2 of the artificial foot 5 relative to the floor 8 is a counter-rotation as compared to the rotative movement R1 of the leg stump 3.

Furthermore, during said hinging of the hinging bar mechanism 10, the distance between the third hinge axis 23 and the fourth hinge axis 24 automatically adapts, which is allowed by said slidable connection 30 of the third bar 13, so as to prevent the occurrence of loss of height of the hip joint 9 (see Figs. 1 and 2) relative to the floor 8.

These aspects are probably best seen in Fig. 6 which shows, in highly schematical form, the hinge axes 21-26 and center lines of bars 11-19 of the planar hinging bar mechanism 10 of Figs. 3, 4 and 5, wherein the full lines indicate positions of the bars 11-19 as shown in the zero position of Fig. 3 whereas the broken lines indicate positions of the bars 11-19 as shown in the hinged condition of Fig. 5. For clarity, the positions of the hinge axes 21-26 as occurring in the hinged condition of Fig. 5 have been indicated in Fig. 6 by appending an apostroph after the respective reference numerals. Hence, in Fig. 6 these positions of the hinge axes in said hinged condition have been indicated by the reference signs 21'-26', respectivelty. Note that also the position of the hip joint 9 (see Figs. 1 and 2) has been indicated in Fig. 6. In Fig. 6, the full line and the broken line that each correspond to the first bar 11 have been drawn extended to this hip joint 9.

Fig. 6 shows that the broken line between the points 23' and 24' (this broken line corresponds to part of the third bar 13) is at an angle to the broken line between the points 21' and 22' (this broken line corresponds to part of the first bar 11). From Fig. 6 it also follows that the distance between the points 23' and 24' is larger than the distance between the points 23 and 24. This change of distance corresponds to the abovementioned automatical adaptation allowed by the slidable connection 30 of the third bar 13, so as to prevent the occurrence of loss of height of the hip joint 9 (see Figs. 1 and 2) relative to the floor 8.

The planar hinging bar mechanism 10 provides the advantages that it is reliable, compact, lightweight, as well as easy to manufacture and repair. It does not require to be motor driven or electronically controlled.

In the shown example, in said zero position and as seen in said hinging bar plane, the positions of the fifth hinge axis 25 and the sixth hinge axis 26 are mutual mirrow image positions relative to the zero line 20 (see Fig. 3). Such a symmetry promotes that the extent of said responsive counter-rotation of the artificial foot 5 is similar for both directions of rotation of the leg stump 3 around the hip joint 9 in the frontal plane.

Also, in the shown example, as seen in the hinging bar plane, the distance between the fourth hinge axis 24 and the fifth hinge axis 25 is larger than the distance between the fifth hinge axis 25 and the third hinge axis 23. Such a property promotes an effective and substantial responsive rotation of the foot 5.

It is remarked that it may optionally be provided that the first bar 11 and/or the second bar 12 and/or the third bar 13 and/or the fourth bar 14 and/or the fifth bar 15 and/or the sixth bar 16 and/or the seventh bar 17 and/or the eighth bar 18 and/or the ninth bar 19 is, or are each, length adjustable into different lockable lengths. Such adjustability allows for easily adapting the characteristics of the prosthesis 1 in dependence of an amputee's wishes and/or needs. It also enables the manufacture of more or less standardized prostheses which may easily be made individually applicable to various dimensions of amputees, leg stumps, artificial feet or artificial knees.

In the foregoing specification, the invention has been described with reference to specific examples of embodiments of the invention. It will, however, be evident that various modifications and changes may be made therein without departing from the broader scope of the invention as set forth in the appended claims.

For instance, in the shown examples, the amputee has a natural knee with a lower leg stump and the prosthesis is connected with a stump socket to this lower leg stump. However, the prosthesis according to the invention may also be arranged such that in its use condition the stump socket is interposed between an upper leg stump and an artificial knee. Such an artificial knee may be part of or connectable to the prosthesis according to the invention.

However, other modifications, variations and alternatives are also possible. The specifications and drawings are, accordingly, to be regarded in an illustrative rather than in a restrictive sense.

Claims

1. A lower leg prosthesis for an amputee (2) who has at least one leg having a lower or upper leg stump (3), the prosthesis (1; 101) comprising:
- a distal end (4) forming an artificial foot (5), or the distal end (4) being connectable to an artificial foot (5); and
- a proximal end (6) forming a stump socket (7) for connection to said leg stump, or the proximal end (6) being connectable, optionally via an artificial knee, to a stump socket (7) for connection to said leg stump;

wherein a use condition of the prosthesis is defined by the distal end actually being connected, if applicable, to said artificial foot, the proximal end actually being connected, if applicable, to said stump socket, and said stump socket actually being connected to said leg stump of said amputee;

characterized by a mechanism (10; 110) which is arranged such that, in said use condition of the prosthesis and in an upright position of said amputee (2) with said artificial foot resting on a floor (8), in response to the amputee performing a rotative movement of said leg stump (3) around its corresponding hip joint (9) while keeping said artificial foot resting on the floor, said rotative movement at least occurring in the frontal plane of the amputee and in one rotation direction (R1) within the frontal plane, the prosthesis causes said artificial foot (5) to rotate relative to the floor at least in the other, i.e. opposite, rotation direction (R2) within the frontal plane.

2. A lower leg prosthesis according to claim 1, wherein said mechanism (10; 110) furthermore is arranged to prevent, during said rotative movement of said leg stump (3) and said responsive rotating of said artificial foot (5) still resting on the floor, the occurrence of loss of height of the hip joint (9) relative to the floor (8),

at least when said rotative movement of said leg stump around the hip joint, as seen in the frontal plane, is unidirectionally performed over at least five degrees in said one rotation direction (R1) starting from a position in which the leg stump is extending vertically under the hip joint, and

at least when said rotative movement of said leg stump around the hip joint, as seen in the frontal plane, is unidirectionally performed over at least five degrees in said other, i.e. opposite, rotation direction (R2) starting from said position in which the leg stump is extending vertically under the hip joint.

3. A lower leg prosthesis according to claim 1 or 2, wherein the mechanism is a planar hinging bar mechanism (10) having a hinging bar plane which in the use condition is parallel to the frontal plane of the amputee (2), the planar hinging bar mechanism comprising at least nine bars extending parallel to the hinging bar plane and hingingly interconnected with one another via at least six hinge axes extending perpendicular to the hinging bar plane, the at least nine bars comprising a first bar (11), a second bar (12), a third bar (13), a fourth bar (14), a fifth bar (15), a sixth bar (16), a seventh bar (17), an eighth bar (18) and a ninth bar (19), the at least six hinge axes comprising a first hinge axis (21), a second hinge axis (22), a third hinge axis (23), a fourth hinge axis (24), a fifth hinge axis (25) and a sixth hinge axis (26);

wherein, as seen in said hinging bar plane, in a zero position of the planar hinging bar mechanism the first hinge axis (21), the second hinge axis (22), the third hinge axis (23) and the fourth hinge axis (24) are lying spaced from one another on a straight line, indicated as zero line (20), with the second hinge axis lying between the first hinge axis and the third hinge axis and with the third hinge axis lying between the second hinge axis and the fourth hinge axis, whereas the fifth hinge axis (25) is lying on one side of the zero line (20) at orthogonal lateral distance from a portion of the zero line between the third hinge axis and the fourth hinge axis, and the sixth hinge axis (26) is lying on the other, opposite side of the zero line (20) at orthogonal lateral distance from said portion of the zero line;

wherein the at least nine bars being hingingly interconnected with one another via the at least six hinge axes is realized in that the first bar is hingingly connected to the first hinge axis and to the second hinge axis, the second bar is hingingly connected to the second hinge axis and to the third hinge axis, the third bar is hingingly connected to the third hinge axis and to the fourth hinge axis, the fourth bar is hingingly connected to the first hinge axis and to the fifth hinge axis, the fifth bar is hingingly connected to the first hinge axis and to the sixth hinge axis, the sixth bar is hingingly connected to the fifth hinge axis and to the fourth hinge axis, the seventh bar is hingingly connected to the sixth hinge axis and to the fourth hinge axis, the eighth bar is hingingly connected to the fifth hinge axis and to the third hinge axis, and the ninth bar is hingingly connected to the sixth hinge axis and to the third hinge axis;

wherein all said hinging connections between said bars (11-19) and said hinge axes (21-26) are non-sliding hinging connections, i.e. not allowing sliding, in the hinging bar plane, of such a bar relative to its corresponding hinge axes, except for the fact that the connection of the third bar (13) to only one of the third hinge axis (23) and the fourth hinge axis (24) is a slidable connection (30) allowing sliding of the third bar relative to said only one hinge axis back and forth in a sliding direction (S1) extending, in the hinging bar plane, through the third hinge axis (23) and the fourth hinge axis (24); and

wherein ends of the first bar (11) and the third bar (13), respectively, are forming said proximal end (6) and said distal end (4) of the prosthesis (1), respectively, or vice versa.

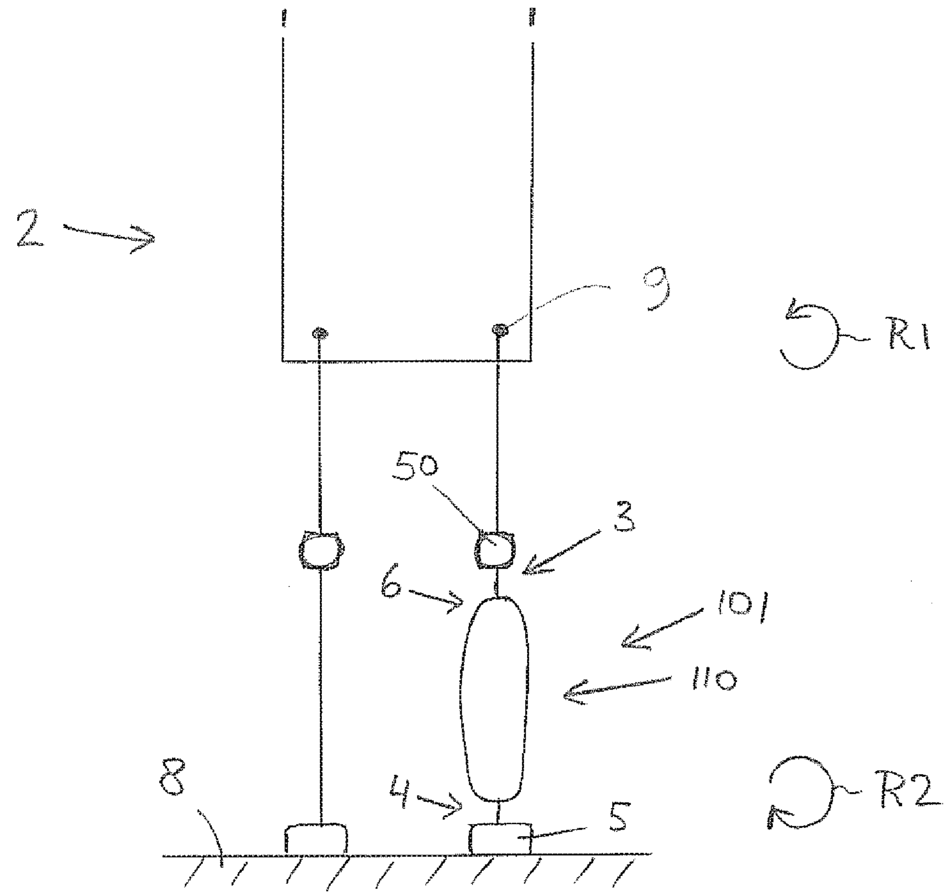
4. A lower leg prosthesis according to claim 3, wherein, in said zero position and as seen in said hinging bar plane, the positions of the fifth hinge

axis (25) and the sixth hinge axis (26) are mutual mirrow image positions relative to the zero line (20).

5. A lower leg prosthesis according to claim 3 or 4, wherein, as seen in the hinging bar plane, the distance between the fourth hinge axis (24) and the fifth hinge axis (25) is larger than the distance between the fifth hinge axis (25) and the third hinge axis (23).

6. A lower leg prosthesis according to any one of claims 3 through 5, wherein the first bar (11) and/or the second bar (12) and/or the third bar (13) and/or the fourth bar (14) and/or the fifth bar (15) and/or the sixth bar (16) and/or the seventh bar (17) and/or the eighth bar (18) and/or the ninth bar (19) is, or are each, length adjustable into different lockable lengths.

Fig. 1



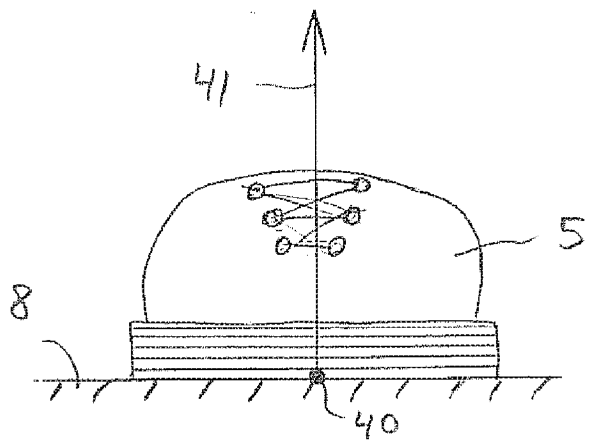


Fig. 2

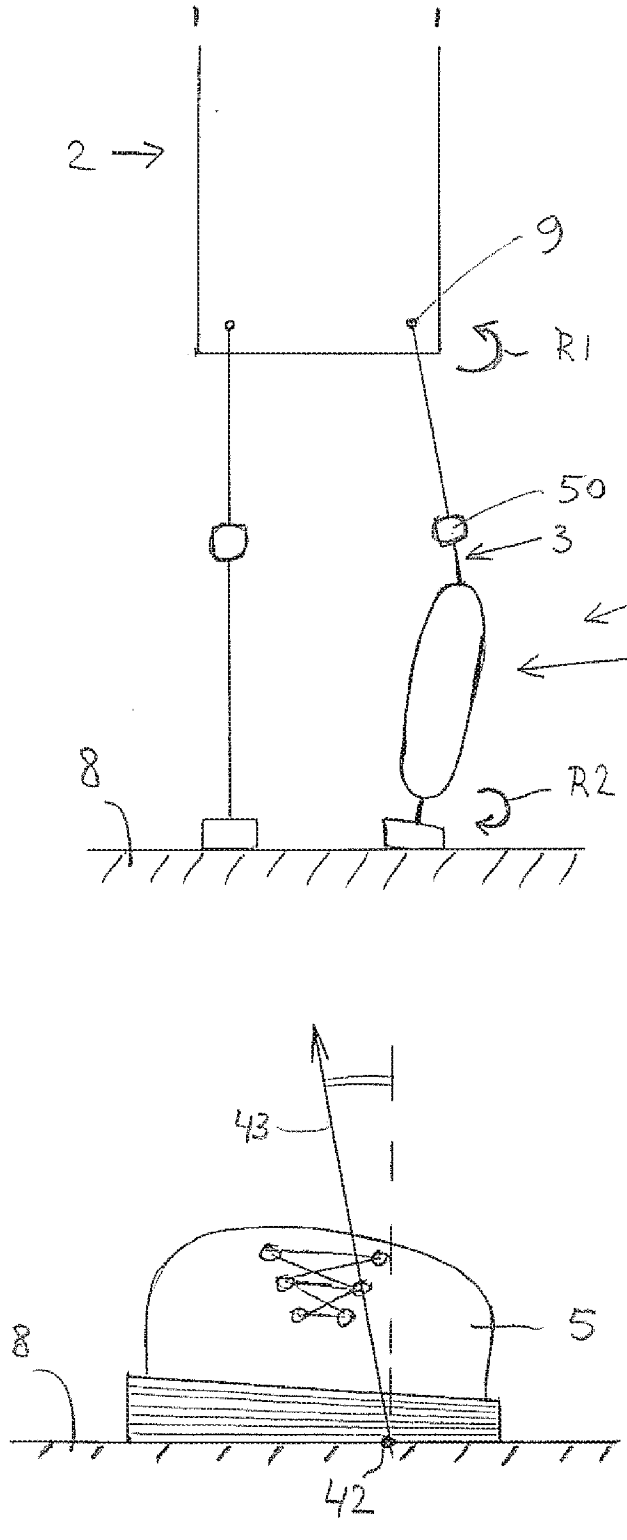


Fig.3

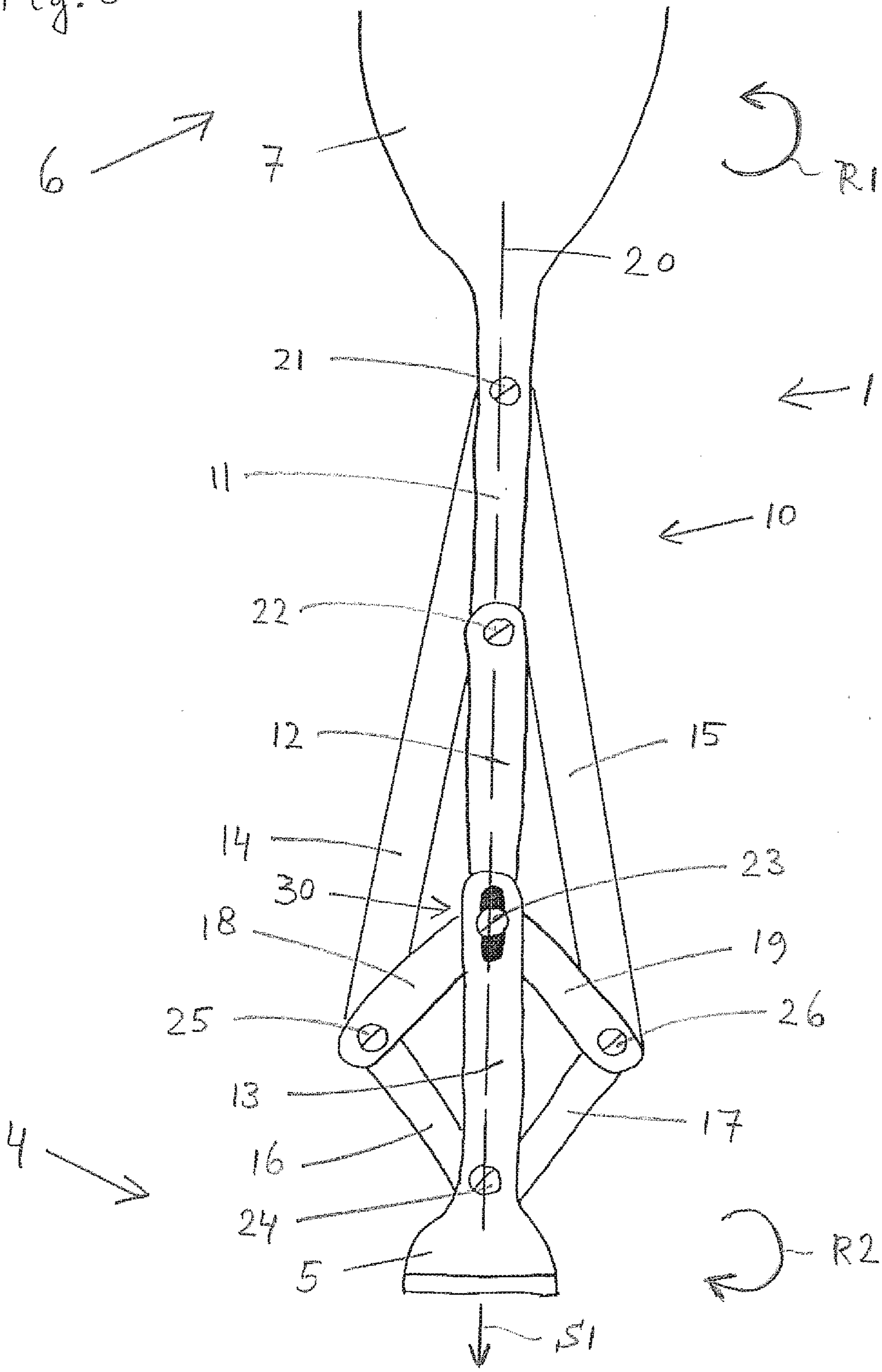


Fig. 4

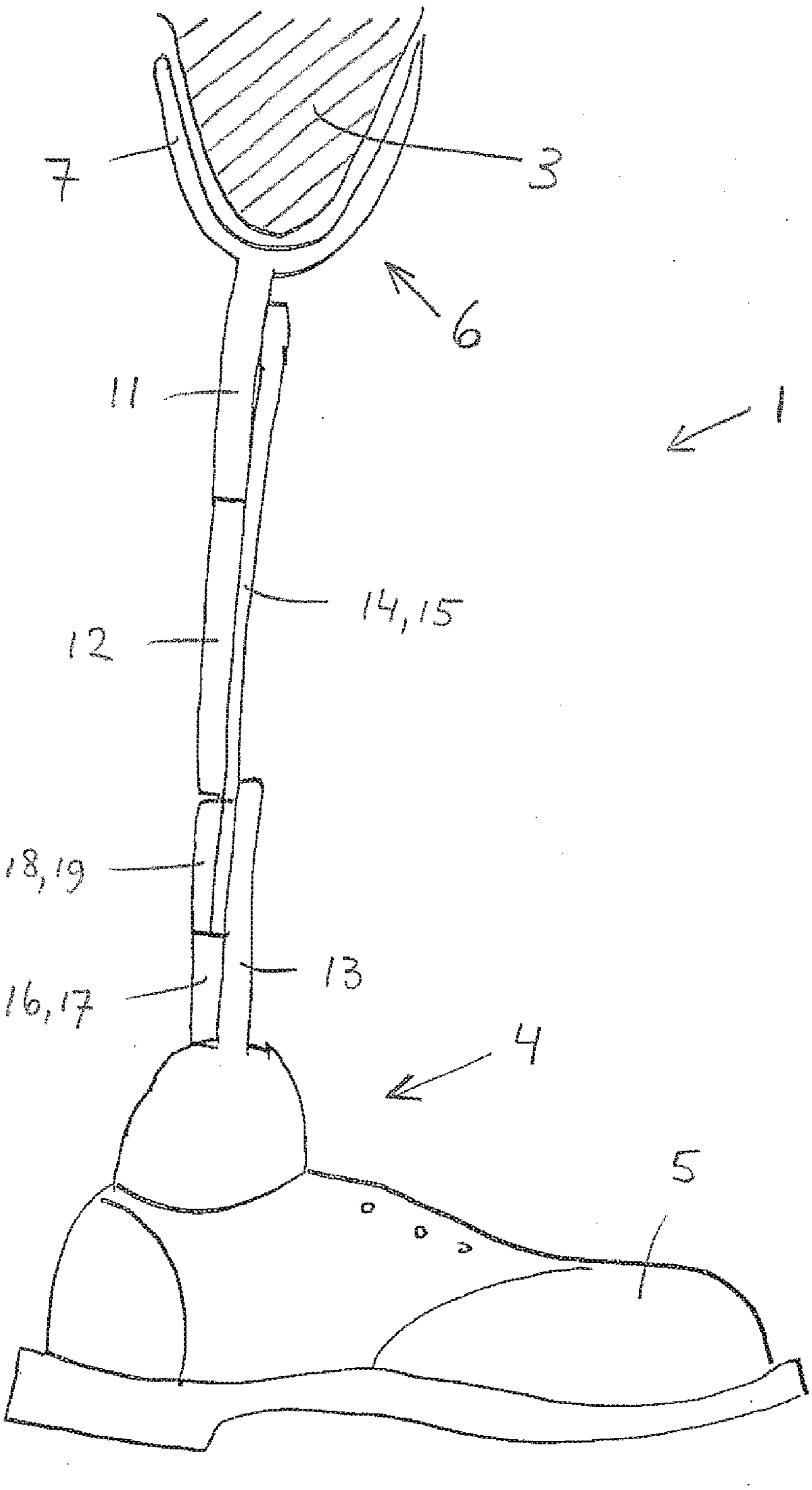


Fig. 5

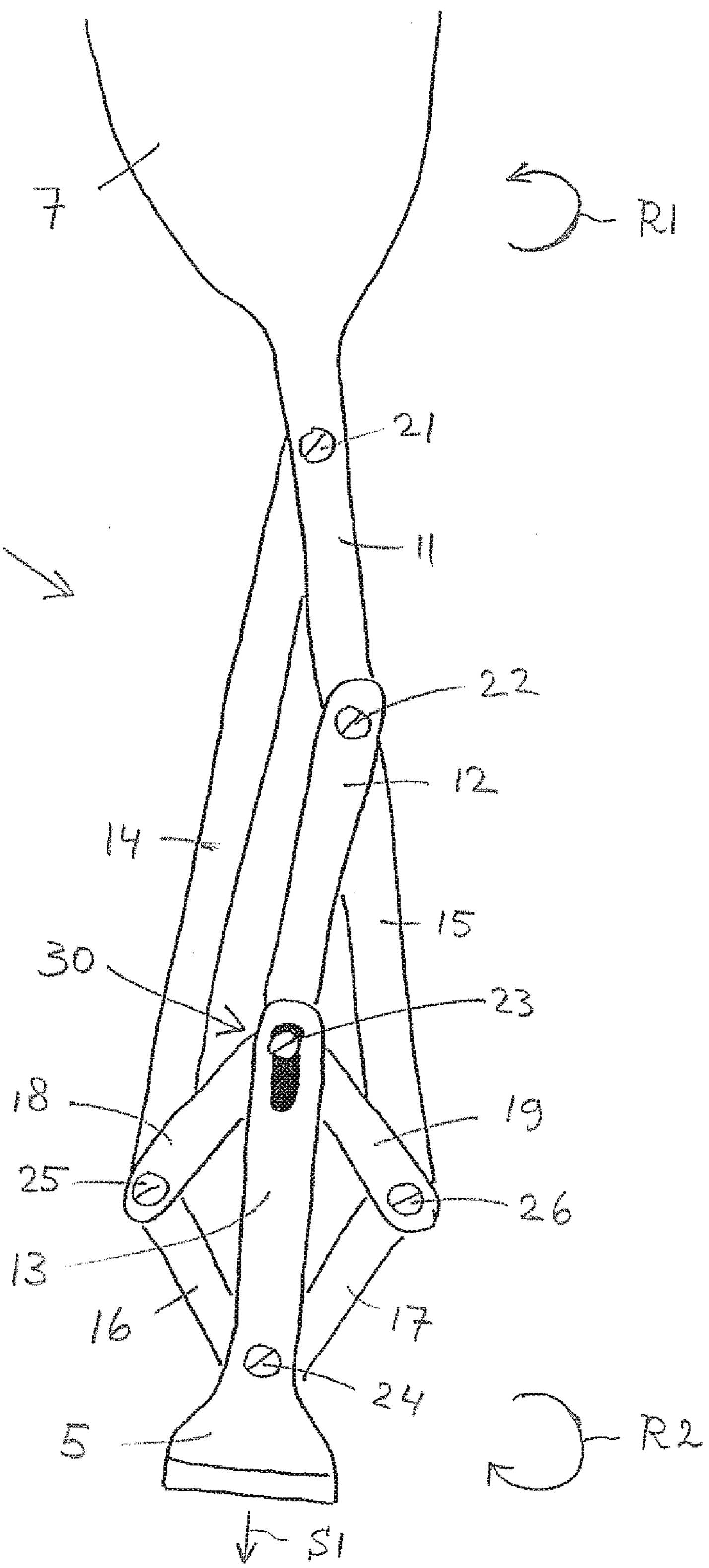
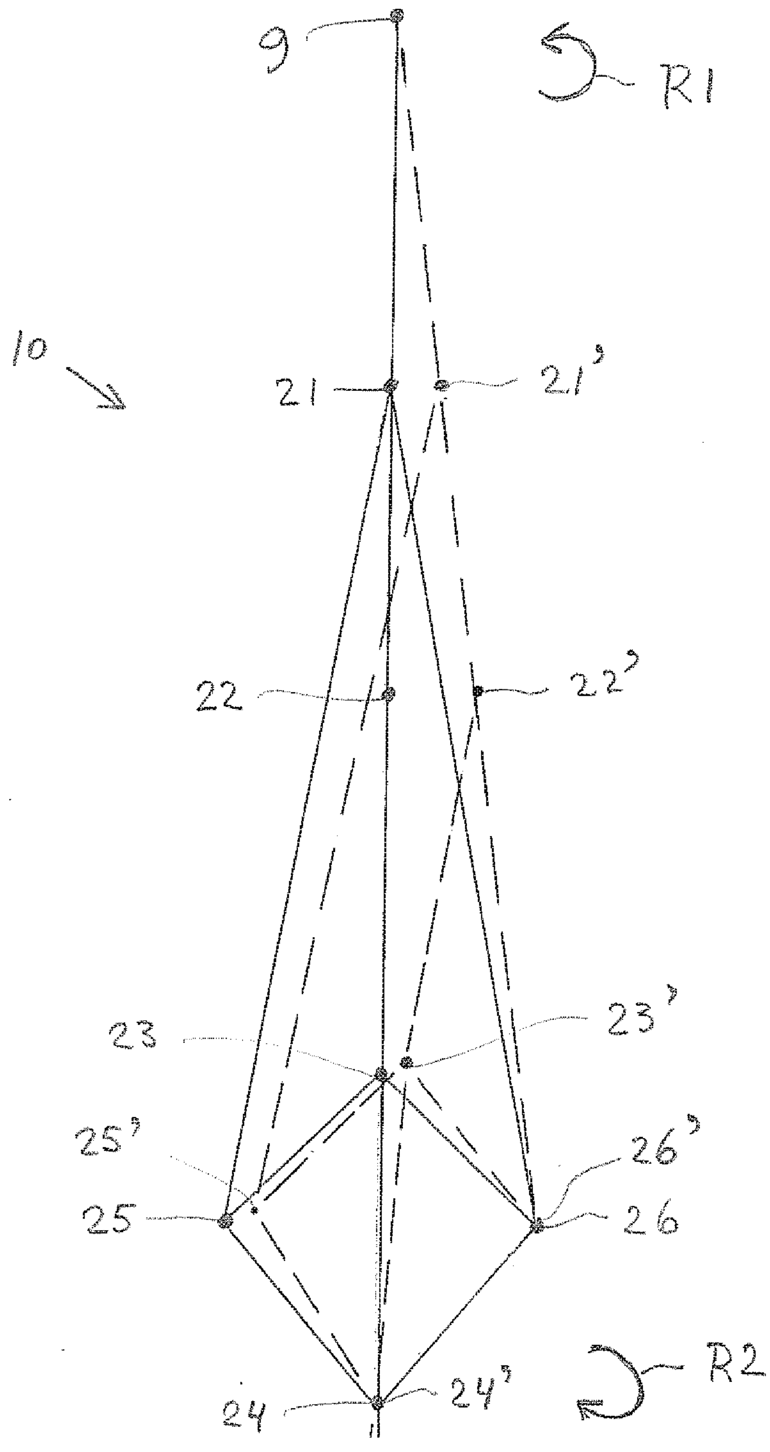


Fig. 6



INTERNATIONAL SEARCH REPORT

International application No
PCT/NL2011/050845

A. CLASSIFICATION OF SUBJECT MATTER
INV. A61F2/60
ADD.

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, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 1 340 478 A2 (HONDA MOTOR CO LTD [JP]) 3 September 2003 (2003-09-03) abstract; figures 1-8 paragraphs [0004] - [0006], [0050] - [0053], [0058] - [0067] -----	1-6
A	WO 2006/118149 A1 (SAIGA YASUYOSHI [JP]) 9 November 2006 (2006-11-09) abstract; figures 4,22 -----	1-6
A	US 4 520 512 A (LEHNEIS HANS R [US] ET AL) 4 June 1985 (1985-06-04) abstract; figure 3 column 4, lines 15-21 -----	1-6

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

☒ See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
20 March 2012	28/03/2012

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/NL2011/050845

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