Chapter 19
WRIGHT STATE UNIVERSITY

College of Engineering and Computer Science
Department of Biomedical and Human Factors Engineering
Dayton, Ohio 45435-0001

Principal Investigator:

Chandler A. Phillips (937) 775-5044
chandler.phillips@wright.edu
David B. Reynolds (937) 775-5044

THE TOILEVATOR

Designers: Sherry Kunovic, Steve Poelzing, Tonya Skidmore
Supervising Professor: Dr. Thomas Hangartner
Department of Biomedical and Human Factors Engineering
Wright State University
Dayton, Ohio 45435-0001

INTRODUCTION

Due to physical limitations, many individuals have difficulty moving to and from a seated position. In many cases physical assistance is needed, via another person or a mechanical device. When another person is needed for assistance in using a toilet, embarrassing and uncomfortable situations may arise. Thus, a mechanical device to aid in lifting and lowering a person from a toilet is needed.

There are currently two devices available. The first is an elevated toilet, which adds three to four inches to the standard 14-inch height. The second is a seat attached to a frame with handles, which fits over the installed toilet. Neither of these devices provides a tilting position or additional lifting. Also, since they are both elevated but do not return to the standard toilet height once the individual is seated, they can be uncomfortable and awkward to use.

Also on the market is a reclining chair that lifts and tilts the individual to a near standing position and returns to a seated position at a comfortable height. The Toilevator incorporates this design concept in conjunction with a toilet.

The client has Inclusion Body Myocitis (IBM), a degenerative muscle disease. He has limited strength and range of motion. He currently uses an elevated seat and toilet but has difficulty getting up and down without the help of another person. In order for him to use the toilet independently and easily, he needs a mechanical device that lifts and lowers him to and from a height of at least 26" with a tilt motion.

SUMMARY OF IMPACT

The client can use the toilet comfortably and independently. In time, the design may be patented and marketed, providing an effective solution for other people who have difficulty using the toilet due to physical impairments.

Figure 19.1. The Toilevator.

Figure 19.2. Tilt and Lift Motion of the Toilevator.

TECHNICAL DESCRIPTION

A lift and tilt combination was designed in order to minimize the distance the user must move to and from the seat. It lifts the user to a near standing position and lowers to a comfortable height.

The design of the device had to fit most standard household toilets, especially the client's. The range of motion had to make optimal use of both tilt and lift so that it is effective and comfortable to use, thus eliminating the need for the other devices or personal assistance. Since the design of electrical devices for use near water can be hazardous and difficult, the power lift mechanism had to utilize the household water supply and pressure instead of electricity. The frame must have rails to allow the user to align him in the proper position. It required a no-slip interface at the floor that would resist corrosion. Also, due to the client's weakened condition, the device required an easy user control.

Other specifications were that the Toilevator: allow for slow ascent and descent, incorporate parts suitable for use with water (to prevent rust), include hand rails for user comfort and stability, eliminate movement of the device except for the desired seat lift and tilt, and have no leakage.

Once the desired range of motion was determined, an appropriate power mechanism was needed. A hydraulic cylinder is the best way to power the device, since it is the most commonly used way of utilizing a fluid for power in a confined space. The current cylinder fulfills the related specifications. It is made of PVC, which will not rust when used with water. If properly assembled, it does not leak. It is also made to be used with pressure, and is capable of lifting 250 pounds. PVC pistons are not readily available, but they can be constructed out of standard-size, readily available parts.

Since the frame need only be four inches above the floor, mounting it on the floor, rather than attaching it to the wall behind the toilet, was easier and allowed for more stability. The back holes on the toilet rim were used for stability and anchoring of the frame. Slots in the frame allow for slight adjustment of the frame size to ensure a good fit to any standard household toilet. Reinforcement support beams prevent the frame from buckling under any applied lateral or front to back forces, such as a kick. Handles are attached to the frame to aid the user in proper alignment to the toilet seat.

The three components of the control mechanism are the user control, the valve controls, and the Bowden pull configuration. The user control is a single hand control placed next to the handles of the toilet seat on either the left or right side. It moves along with the toilet seat and controls the motion by opening and closing the control valves in the plumbing. With a single hand control, as opposed to multiple controls or foot actuators, the client can remain stable and easily

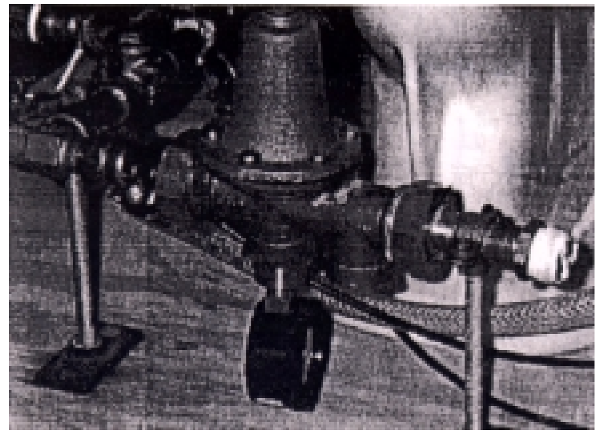

Figure 19.3. Plumbing Assembly

control movement during lifting and lowering. A wide range motion controller is used, since it is less physically challenging to operate than push buttons or switches.

The valves of the control mechanism regulate the flow of water in and out of the pistons, which raise and lower the seat. Ball cock valves manage reservoir levels. The valves are easy to operate, inexpensive, and seal properly. It is also easy to adjust the angle of the lever arm to facilitate opening and closing of the valve with the Bowden pull.

The user control is placed near the handles, which move with the frame during ascent and descent. The valves are secured near the floor under the toilet. The Bowden pull configuration is used to operate the motion. To maintain a neutral position when the control is not in operation, springs are attached to the valves. With this layout the user has control of his motion at all times. When the user lets go of the user control, it returns to the neutral position, closing both valves and stopping the motion. This allows the client to stop and reposition himself if he loses his balance or reverses his motion.

The standard toilet shut-off valve is replaced with a copper T-connection and two separate shut-off valves, one to the toilet and one to the Toilevator. This is the only plumbing modification. A hose attaches the plumbing of the Toilevator to the shut-off valve.

Inside the unit, from the hose connection in the direction of water flow, there is a pressure-reducing valve, which maintains the water pressure at 20 psi. From there, it enters the first ball cock valve, which, when open, allows the pistons to fill, raising the seat. The check valve placed before this valve keeps the valve from opening when the load on the pistons is greater than 20 psi. When the second ball cock valve is opened, water is pushed out of the pistons, lowering the seat. The water empties into the toilet tank through a vacuum breaker, preventing water from entering the drain line from the tank, as required by plumbing code.

The total cost of the Toilevator is $1200.

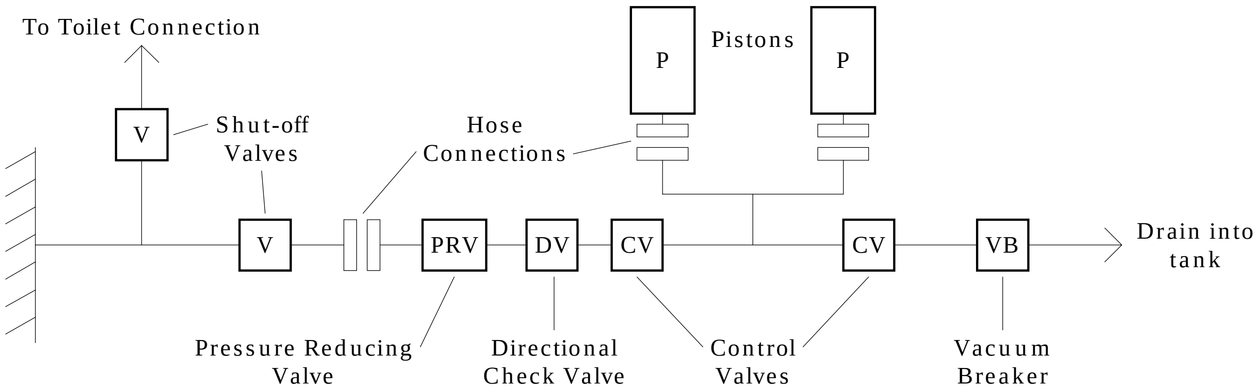

Figure 19.4. Plumbing Diagram.

MULTIPLE RAMP EYE TRACKING DEVICE

Designers: Josh Noble, Anupam Bedi
Client Coordinator: Kim Potter
Supervising Professor: Dr. Ping He
Department of Biomedical and Human Factors Engineering
Wright State University
Dayton, Ohio 45435-0001

INTRODUCTION

A ball drop toy in a classroom was modified for students with cognitive and motion tracking disabilities. The toy incorporates a series of five wooden ramps and a racquetball. The ramps have a hole cut into alternating ends to allow the passage of the ball. This configuration allows a student to drop a ball through the uppermost hole and watch the ball roll down the series of ramps until it drops through the hole in the last ramp. At this point, the ball is held in the base of the ball drop until the student starts the process over again.

Prior to the modification, students in wheelchairs were excluded from play with the toy because they could not reach the top hole, four to five feet off the ground. One student, with only a single digit on the distal end of each arm, was unable to grasp the ball, so was also excluded from play.

All of the students are capable of activating switches centered at their chests.

The manually operated device was made completely automatic by incorporating an elevator to carry the ball to the top of the ramp. Three switches control the elevator system, one starting the motor, a second automatically stopping the motor when the elevator reaches the top, and the third stopping the elevator at the bottom.

Design requirements included that it be easy to move and stable, and that it operate via a rechargeable battery due to possible safety hazards associated with power cords.

SUMMARY OF IMPACT

The students were able to adapt to the new modifications to the ball drop toy. All of the students now play with the toy, including those in wheelchairs and those unable to pick up a ball.

Figure 19.5. Multiple Ramp Eye Tracking Device.

TECHNICAL DESCRIPTION

The Multiple Eye Tracking Device involves a configuration that places the motor at the bottom of the toy and uses a 3D chain as a driveline. The system uses an elevator car that is attached to the drive chain on both the top and the bottom of the car. This makes the motor pull the elevator car up and down, and helps keep the car from jamming during downward motion.

The system is composed of three parts: the elevator car, a tilt floor inside the elevator car, and a groove cut into the side of the toy. The system functions by having a tab on the tilt floor run in the groove on the toy's side. When the elevator car nears the top of the toy, the groove ends and forms a stop. The motor continues to lift the elevator car as the tilt floor tab comes into contact with the stop. As the car rises, the tilt floor is forced to move in a rocker motion to expel the ball. A magnetic reed switch is mounted at the top of the elevator shaft to signal when the motor to stop. If it fails to stop, a mechanical limit switch stops the motor, preventing the elevator car from hitting the top of the elevator shaft.

The single-pole double-throw (SPDT) momentary rocker or panel switch initiates the motor drive circuit. When the student pushes it, an output pulse is sent to start the motor. The elevator begins its ascent to the top of the device. Four pulleys and a drive sprocket are used to allow the driveline to run along the shield walls and remain clear of the elevator car as it moves up and down. Once the elevator car reaches the top, it enters the vicinity of a magnetic reed switch, which stops the car and delays the motor, allowing the ball ample time to be released from the elevator car. The motor then begins turning in the opposite direction and the elevator descends to its starting position and stops when it encounters another magnetic reed switch. Both the top and bottom locations have SPDT mechanical limit switches to prevent the elevator from going too far up or down.

The ball travels through the ramps until it reenters the elevator car. A gate prevents the ball from entering the shaft when the elevator is not at its starting position. The gate consists of a small square sheet of acrylic hung by two springs, attached to the side of the device that partially covers the hole. When over the hole, the gate is held in place by two tracks attached at each side.

The total cost of the Multiple Ramp Eye Tracking Device is $750.

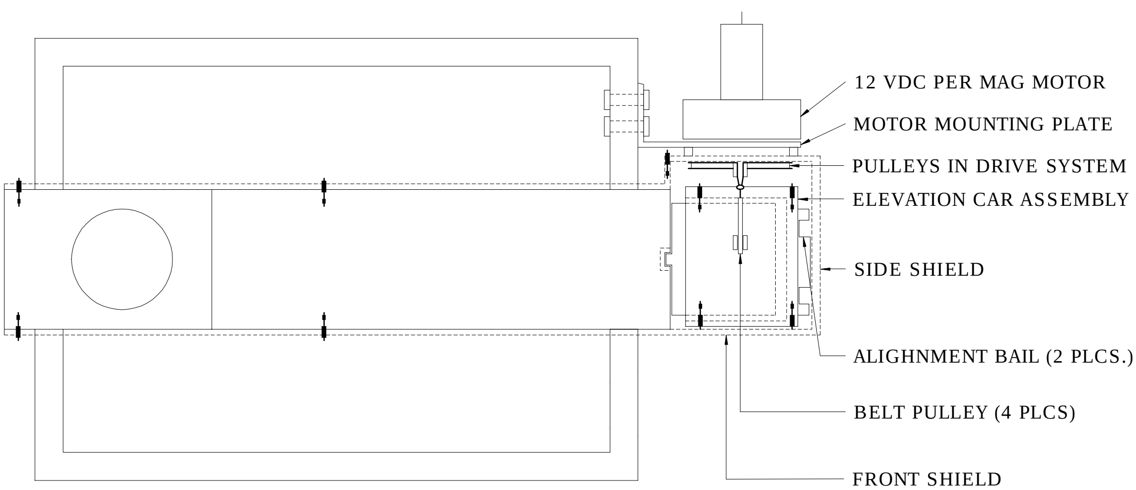

Figure 19.6. Schematic of Drive System: Top View.

PROSTHETIC ALIGNMENT DEVICE

Designers: James Marous, Brian Ruhe
Supervising Professor: Dr. D.B. Reynolds
Department of Biomedical and Human Factors Engineering
Wright State University
Dayton, Ohio 45345-0001

INTRODUCTION

A prosthetic alignment system was designed to maximize fit and functionality of a leg prosthesis for individual patients. Individual prosthetic components must be adjusted for three different axes in order to ensure compatibility and functionality with the user. First, each prosthetic component must be adjusted for rotation about the major axis of the residual limb. Rotating the axis of the prosthetic about the central axis ensures that both the residual limb and the prosthetic lie in precisely the same plane and function as a unit.

A prosthetic system must be able to slide in the medial/lateral (M/L) and anterior/posterior (A/P) directions. The prosthetic component must be aligned so that the prosthetic lies directly under the central axis of the residual limb and does not lie further from this central axis than would cause instability. Finally, a prosthetic alignment system must allow angulation of the prosthetic with respect to the patient's residual limb. A prosthetic alignment system must allow up to 15 ° of angulation with respect to an axis drawn along the center of the residual limb.

Current alignment systems are not designed to be left in the prosthesis permanently, but only to be used during initial alignment and then removed after adequate measurements relating to alignment have been taken. Such systems are heavy and expensive and are not adequate for permanent use. They also do not allow independent adjustment of each axis. Most current systems are comprised of a single bolt threaded through the entire alignment system that holds all three axes pre-set. Loosening the central bolt releases all three axis alignments and requires adjustment of all three axes when the bolt is again tightened.

SUMMARY OF IMPACT

This device allows for independent adjustment of each axis while the prosthetic alignment system is installed on a patient. The unit can be installed on a patient's prosthesis without a significant increase in prosthetic cost. The low weight and thickness ensure no significant added weight or height. The device is durable and allows for high reliability and low maintenance.

Figure 19.7. Prosthetic Alignment Device.

TECHNICAL DESCRIPTIONS

The prosthetic alignment device consists of two circular dishes that slide across each other on a smooth surface. The center square bolt is used to take up torque. Four setscrews are arranged to control slide in the A/P and M/L directions. Each screw is threaded into the center of its respective dish and meets the flat side of the center bolt. When the unit is adjusted to its full slide position, the screw lengths are adjustable. No screw ever protrudes beyond the radius of the dish.

A screw running into the center of the center bolt maintains compression between the dishes. When this screw is tightened, the heads of the bolt are drawn together and the dishes are compressed with respect to one another. The dishes are made of 70-75 aluminum, the center bolt and setscrews of steel, and the rotating pyramid assembly of 4-6 titanium. The aluminum dishes are hard coated with 0.001" anodization. The setscrews have a beveled point to engage the center bolt. To achieve slide of the center bolt, one loosens the setscrews in the direction of travel, and then tightens the opposite screw to lock the center dish in position.

The top dish was made to accept the standard European 4-bolt pattern. The bolts, manufactured separately, are inserted from the bottom of the dish and seated in cutouts in the dish body. These bolts mate to standard 4-hole patterns on the wearer's socket, already an integral part of most prosthetic systems. Each dish is approximately 5/16" thick and 0.78" high.

The center bolt is a square shank and head, compressing the two plates, and controlling torque through the center of the device. The male portion of the bolt seats into the female portion. The bolt is locked into place by a screw threaded into the center through the bottom dish. When this screw is tightened, the male and female portions of the center bolt are drawn together and the bolt fixed. A circular plug is backed into the screw to prevent it from loosening due to vibration while walking. The amount of torque applied

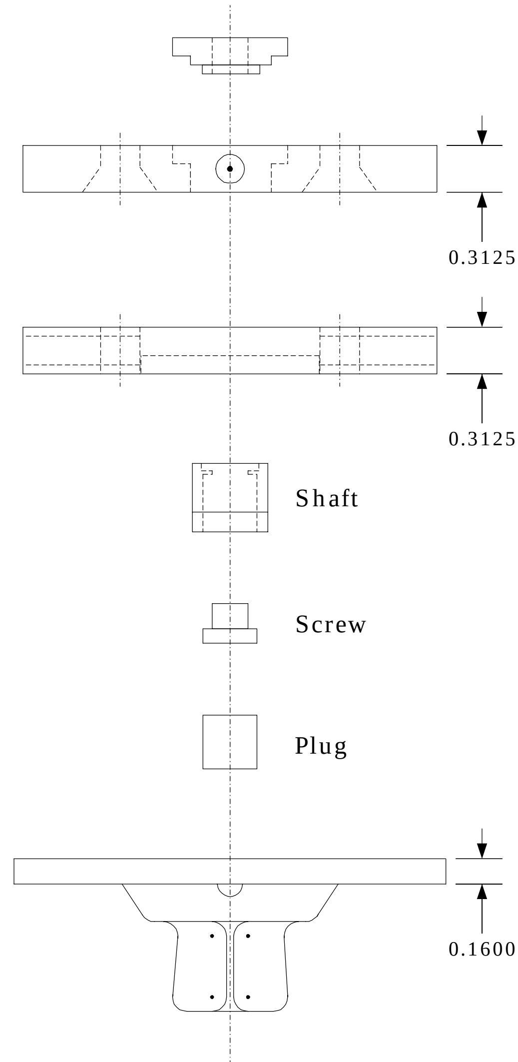

Figure 19.8. Assembly of Prosthetic Alignment Device.

to the center screw determines the amount of compression generated between the plates.

The total cost of the Prosthetic Alignment Device is $400.

A SWITCH DRIVEN MOTOR CONTROLLED ARM FOR POSITIONING A COMMUNICATION DEVICE ON A WHEELCHAIR

Designers: Yogesh Patel, Angelo M. Ripepi, Nedim L. Tosyali
Supervising Professor: Dr. Blair Rowley
Department of Biomedical and Human Factors Engineering
Wright State University
Dayton, Ohio 45435-0001

INTRODUCTION

A motor-driven, switch-controlled arm for positioning a computerized communication device was designed for a 29-year-old woman with cerebral palsy. The client is non-verbal and uses a communication device from the Prentke Romich Company. She remains seated in her wheelchair throughout the day. Because of limited motor ability in her arms, she cannot move the communication device to the front of her lap tray or control a Prentke Romich mounting system without the assistance of another person.

The communication device is fixed on a mechanical arm that moves from the back of the wheelchair to the desired location in front. The arm enables the client to position independently her communication device. The device is operable with a switch that uses the 24-volt DC power from her wheelchair.

SUMMARY OF IMPACT

The new motor controlled arm for positioning a communication device enables the client to communicate more independently with her teachers and family.

TECHNICAL DESCRIPTION

The design involves a mechanical arm that moves from the back of the wheelchair to the desired location in front. Specifications included that the device: operate with the batteries provided with the wheelchair; have minimal control switches; be made of durable, weather-resistant material; have easily accessible circuitry, sealed for all weather conditions; have a soft switch, requiring minimal finger pressure; and be properly grounded.

The design incorporates a rotational motor for rotation over the head, a stainless steel rod that bends 90 ° and attaches to the motor, and a counterweight block

Figure 19.9. A Switch Driven Motor Controlled Arm for Positioning a Communication Device on a Wheelchair.

of steel that attaches to the shaft. A support wheel, seen on the bottom of the communication device, provides support when the device is positioned on the lap tray. The storage position in the back includes a pedal switch that opens the circuit and, when depressed, prohibits backward motion of the communication device. The switch is mounted on the backrest in the rear of the wheelchair.

The rotational motor is a Barber-Colman DC motor, which can produce 300 in-lbs. of torque and rotate at 2.3 rpm. The mounting of the motor had to be stable and strong enough to handle the weight of the motor, the communication device, and the counterweight. Two aluminum plates are used for the mounting. The two plates are bolted together at a 90 ° angle. The larger plate is mounted on the rods of the backseat and the other allows for the attachment of the motor on the right side of the chair. The battery source is the 24-volt Invacare wheelchair power supply. The pedal switch is mounted on the backrest to stop the backward motion of the communication device. The momentary switch is the control mechanism used by the client to position the communication device.

The total cost is $950.

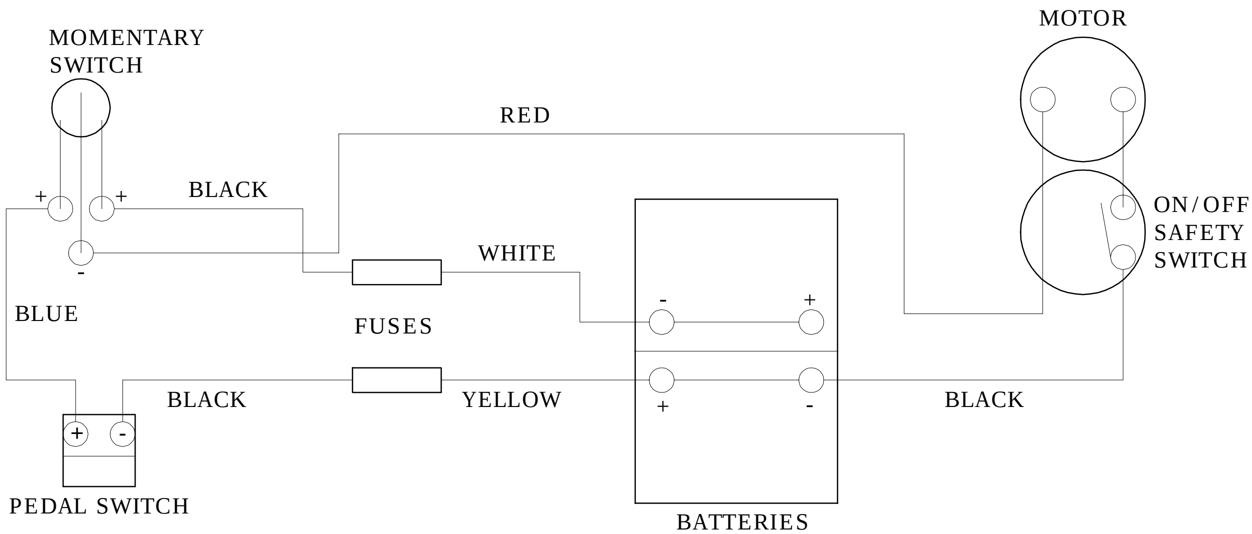

Figure 19.10. Circuitry for the Switch Driven Motor Controlled Arm

BENCH ALIGNMENT AND MEASUREMENT DEVICE

Designers: Eric Day, Amy Judy
Supervising Professor: Dr. David Reynolds
Department of Biomedical and Human Factors Engineering
Wright State University
Dayton, Ohio 45435-0001

INTRODUCTION

Precise means of measuring needed distances and angles for the production and alignment of prosthetic limbs are inefficient and inaccurate. Currently, practitioners use crude devices, loosely held tape measures, and plumb-bobs to estimate these values. Patients often spend countless hours with practitioners, making adjustments until a prosthesis fits properly.

There are several steps in fitting a patient for a prosthesis. The determination of a patient's activity level, casting of the residual limb, marking of all landmarks and bony prominences, and choice of the appropriate type of prosthetic to be made are all important steps. Human error can increase the time to make needed adjustments for a comfortable fit. Sometimes, sockets must be completely remade.

A laser system, the Bench Alignment and Measurement Device (BAMD), allows exact alignment and measurement. A wide-angle perspective is gained by increasing the distance from the patient, yielding a better assessment of socket alignment.

SUMMARY OF IMPACT

The BAMD may help reduce costs because of less time spent by prosthetists. The BAMD may prevent errors in alignment, saving additional labor and material costs. Original testing has involved above—the-knee amputees (AKA), but the BAMD could also be used for alignment of the socket for below-the-knee amputees (BKA) as well

TECHNICAL DESCRIPTION

Medical Alignment Systems, a company in Salt Lake City, Utah, produced a laser to allow for the generation of the needed reference lines. This company currently manufactures radiation alignment lasers used in hospitals and clinics. By combining the different lasers, developers constructed a system with constant vertical and rotational lines.

Figure 19.11. Bench Alignment and Measurement Device.

The BAMD consists of four components: the laser unit, tripod, macro slider, and measurement stand. The laser unit is comprised of two laser beams diffused through a small curved lens (actually, a glass rod). The first laser beam produces a fixed vertical reference line, used to determine the patient's load line, running through the knee center. The second laser beam intersects the vertical line at knee center and rotates about this center. This beam is used to connect the knee center and any desired anatomical landmark, most often the Ischial Tuberosity. These projected lines are then traced directly onto the test socket and enable the prosthetist to use these visual references in the final assembly and alignment of the prosthesis.

The laser unit has a three-meter focal length and uses 630 nm wavelength diodes. It is critical the unit be level, positioned at the focal length, and perpendicular to the frontal plane of the patient. There are two bubble levels mounted on the laser unit to verify that the laser line is true vertical or horizontal, depending on unit orientation.

A standard camera/camcorder tripod provides support for the unit, and allows for the range of position adjustment needed. The tripod head tilts to hold the laser unit in a vertical mode, for alignment and angle projection, or in a horizontal mode, for distance measurement. The tripod has a height range of 13” to 61”, which exceeds the expected 14” to 54” range, based on an average height range of 4’10” to 6’4”.

The Macro Slider provides a forward/back adjustment range of 3.125” and left/right adjustment range of 4.5”. This allows the laser unit to be positioned correctly without moving the tripod back and forth or side to side. The correct position is at the focal length and perpendicular to the frontal plane of the patient.

The measurement stand, in conjunction with the laser unit in the horizontal mode, provides the necessary length measurements. It is 61” tall. The vertical post and side supports are constructed of 1”x 6” pine mounted on a 1.25”x 15” sandwiched pine base. Mounted on the vertical post is a measurement tape with a range of 11.5” to 58.5” and a Plexiglas note board.

The approximate cost of this device is $750. The cost was kept reasonable thanks to the donation of the laser and the labor involved in its manufacture by Medical Alignment Systems.

Figure 19.12. Taking Measurements with the BAMD.