Measurement of prosthetic alignment

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Abstract

An essential part of alignment description is the position and orientation of the socket relative to the rest of the limb. Repeatable measurements of these parameters is hindered by the non-geometrical shape of the socket. A unique axis system has already been defined to enable such measurements to be carried out. The method however, employs an iterative technique and is time consuming. A simple device to facilitate these measurements has been developed and is reported.

Introduction

It is everyday prosthetic practice to align lower limb prostheses using bench and dynamic alignment procedures. Bench alignment is the initial setting up of the limb to a prescribed geometry, whereas dynamic alignment is the subsequent modifications made during walking trials. The prosthetist using his own judgement and the feedback from the patient aims to achieve the most suitable limb configuration for the function and the comfort of the patient. This limb configuration is known as the "optimum alignment", and it is generally believed that for a given patient and prosthesis this is unique.

The parameters involved in describing alignment are in everyday use and are referred to in the literature (Radcliffe 1955, 1961). The orientation and position of the socket relative to the rest of the limb is one of the most essential parts of this description. However, until recently the non-geometrical shape of the socket has prevented accurate alignment measurement. The first efforts in making repeatable measurements of socket alignment relate to a comparative study of various below knee (BK) modular assembly prostheses (Solomonidis, 1975). Repeatability was achieved by defining a unique axis system for the patellar tendon bearing (PTB) socket, and this definition was later extended to above knee (AK) level (Lawes et al., 1975). The measurement technique however, utilized an iterative approach and was therefore time consuming. A simple device has been developed to facilitate alignment measurement and is reported here.

Reference axes

To specify the position and orientation of the components of a prosthesis in three dimensions it is necessary to have a frame of reference to which all measurements may be referred. The reference system used will be described briefly as it forms the basis for all measurements. It consists of a set of orthogonal axes with its origin at the "ankle joint" centre. The ankle centre is arbitrarily defined as the centre of the bolt hole on the top surface of the SACH foot. A similar origin can be also defined when uniaxial feet are used. However, as all legs measured had SACH feet no effort has been made in this direction. The top surface of the SACH foot is taken to form the x-z plane, the y axis thus being normal to it.

The descriptions such as anteroposterior or mediolateral in relation to the lower limbs are generally rather loosely used. There is no universal agreement whether they relate to the direction of locomotion or the plane formed by the shank and thigh when the knee is flexed. This may not be critical for general descriptive purposes. However, when quantifying the geometry of a prosthesis forward and sideways directions must be defined. For AK prostheses the normal to the projection of the knee flexion/extension axis (i.e. the knee bolt axis) onto the x-z plane is taken as the forward direction (x axis) and the z axis in turn is obtained to form a right handed orthogonal system. The forward direction for BK prostheses is defined using the socket reference axes.
The socket axes definitions are detailed by Lawes et al (1975). Here only a brief description relating to below knee PTB and above knee quadrilateral sockets will be given.

**PTB socket**

Two parallel planes on levels contained within the socket are used, one located 25 mm from the distal end of the socket and the other 25 mm distal to the patellar bar (Fig. 1). Initially the patellar bar level was considered for the location of the top plane (Solomonidis, 1975). However this was later modified as the posterior brims of some sockets do not reach this level. In plan view the positive z axis is defined to be parallel to the posterior brim, lie in the top plane and be directed towards the patient's right. The y axis is located equidistant from the socket walls both anteroposteriorly and mediolaterally in the two planes (proximal direction as positive). The x axis is chosen to form a right handed orthogonal set.

**Quadrilateral socket**

Again two parallel planar levels are established. One located 25 mm from the distal end of the socket and the other 25 mm distal to the ischial seat. Positive x axis is defined to be parallel to the flat medial brim in plan view and anteriorly directed. The y axis is established as in the case of PTB sockets and the z axis is chosen to form a right handed orthogonal set.

Both below and above-knee axes definitions provide a unique co-ordinate system for each particular socket.

**Alignment measurement**

The three axes for each system so defined can only be determined simultaneously. The orientation of the x–z plane can be established if the y axis is known, and in turn the y axis can not be located until the x–z plane is fixed. The initial measurement technique therefore, employed an iterative procedure as described by Lawes et al (1975). First the two planes and the x and z axes were estimated and then corrections were made depending on the calculated inclination between the y axis and the x–z plane. The procedure was repeated until an orthogonal set of co-ordinate axes were obtained. Although this procedure gave repeatable results it was very time-consuming, and therefore alternative measurement techniques were sought. As a result a socket axes locator, seen fitted to a socket in Figure 2, was designed and manufactured. This consists of a central rod upon which are mounted two sets of mutually perpendicular arms. One set is located 25 mm from one end of the rod. Its arms consist of chains of four bar linkages, where the central links have common members to keep the two arms and the rod mutually aligned.

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Fig. 1. Reference axes for a below-knee PTB socket (see text).

Fig. 2. Socket axes locator seen fitted to an above-knee socket. The prosthesis is bolted by the foot-fastening bolt to the measuring table.
Measurement of prosthetic alignment

orthogonal. The rod forms the pivot point so that when each arm is extended to touch the inner socket wall the rod remains equidistant from the tips of the arm. The second set of arms are similarly constructed and mounted on a sliding carriage and a groove in the rod prevents the rotation of the carriage thus maintaining the two sets of arms parallel to each other. The carriage is clamped to the rod in the upper socket plane with a lock screw. Adjustment of the arms, which remain in position due to frictional resistance in the joints, causes the central rod to be aligned as the y axis of the socket.

The prosthesis to be measured is bolted by the foot fastening bolt, after the SACH foot is removed, to a vertical bracket at one end of the measuring table (Fig. 2). The table forms a surface parallel to the mediolateral plane (y-z reference plane) and a grid is inscribed on it for ease of measurement. A scribing block is used on the table top so that its pointer is adjusted to touch in turn the various reference points on the limb and the socket axis locator. By measuring the position of the scribing block on the grid and the height of the pointer above the surface of the table the three co-ordinate dimensions for each reference point can be obtained.

Experience to date using the socket axis locator has shown that the technique is satisfactory in establishing a socket reference axis system. Measurements of a pre-set alignment proved that any reference point can be repeatedly defined to an accuracy of ±1 mm.

The system is presently being used in assessing the significance and repeatability of optimum alignment, and the effects of alignment variations on the load actions transmitted by prostheses.

REFERENCES


