Brace Alignment Considerations

By HANS R. LEHNEIS, C.P.O.*

I. An Approach to Brace Alignment

The construction and alignment of a brace cannot be based solely on the condition of the disabled limb for which the brace is intended. A functionally or structurally deficient extremity that is to be braced must be considered as part of the body as a whole. Special attention must be given to the normal static and dynamic relationships of the hip, knee, ankle, and subtalar joints. If these normal relationships are not taken into account during alignment procedures, the brace may hinder the performance of the wearer and may tend to increase further any existing deformities.

An approach to correct brace alignment and an analysis of mal-alignment are presented in this paper. Included in the discussion are alignment considerations in the frontal and transverse planes, and the relationship of bracing procedures to normal anatomical alignment. The functions of the ankle and sub-talar joints are reviewed first, to assist in the understanding of procedures involved in ankle joint alignment. It will be noted that knee joint function is not reviewed here. Since most long leg braces eliminate knee motion with a knee lock, alignment considerations at the knee during standing and walking are of little significance.

II. A Review of Joint Functions

A. *The Ankle Joint*—Due to the natural torsion of the tibia, the axis of the ankle joint is rotated externally 20 to 30 degrees with respect to the knee axis. (Figure 1). Tibial torsion is a developmental phenomenon which increases from a minimal amount of about 2 degrees in the newborn, to a permanent value of 20 to 30 degrees by the age of 7 years. This developmental adaptation places the ankle joint in the best position for upright walking.

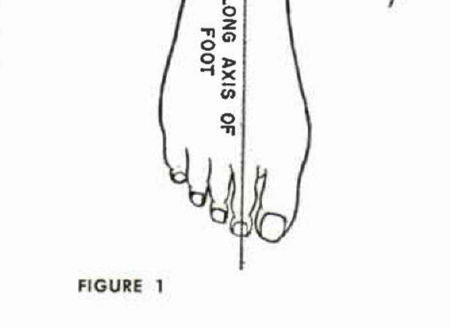

FIGURE 1

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During normal walking, the center of gravity of the body oscillates from side to side as it moves forward. (Figure 2).

FIGURE 2

The axis of rotation of the ankle joint is not perpendicular to the line of progression during the first half of stance phase. (Figure 3). Rather it is approximately perpendicular to the path of the center of gravity of the body, which permits the ankle joint to bend freely in the direction of movement of the center of gravity from heel strike to the mid-stance phase of walking.

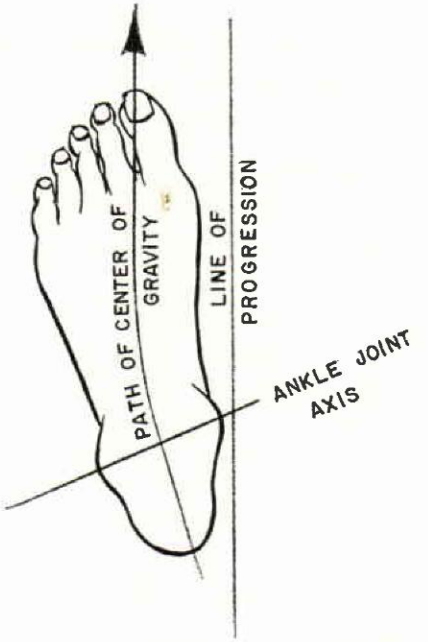

FIGURE 3

B. *The Sub-Talar Joint*—The subtalar joint performs three especially important functions:

1. In standing, it permits mediolateral shifting so that the center of gravity can be maintained within the base of support, while the foot retains flat heel and sole contact with the floor.

2. It permits the feet to adapt to uneven ground.

3. During flexion of the knee, as in squatting, it helps to compensate for the difference in alignment of the ankle joint and the knee joint, as projected in the transverse plane. (Figure 1).

III. Alignment Considerations in the Frontal Plane

A. *Objectives*—The alignment of the brace with respect to the frontal plane should be such that:

1. The foot will be flat on the floor in standing and during the appropriate portions of the stance phase of walking.

2. The mechanical joints will correspond with the anatomical joints.

The most convenient way to achieve these objectives is to relate the alignment of the brace to anatomical reference lines.

B. *Reference Lines*—In the normal standing position, a vertical line dividing the body into equal right and left halves passes through the nose, the umbilicus, the center of gravity and the symphysis pubis. This line is referred to as the *mid-sagittal line*. It is important to note that this line bisects the space between the knee and ankle joints. (Figure 4).

In normal standing, a line through the center of the hip, the knee and ankle joints, projected on the frontal plane, will be parallel to the *mid-*

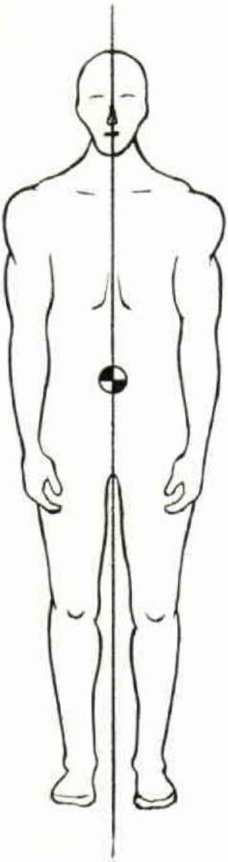

FIGURE 4

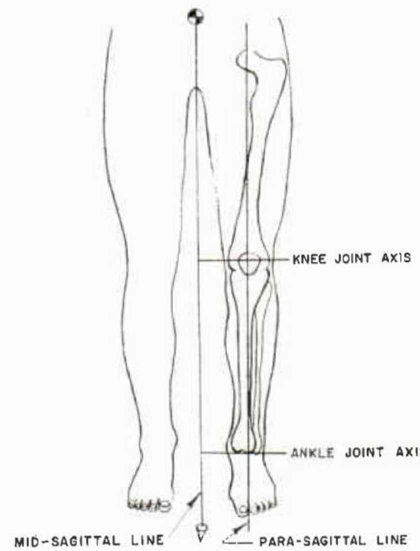

FIGURE 5

sagittal line. This line through the joint centers is referred to as the *para-sagittal line.*

C. *Joint Alignment*—The axes of of rotation of the knee and ankle are perpendicular to the *mid-sagittal* and *para-sagittal lines.* (Figure 5).

By orienting the shoe, brace joints, and bands perpendicular to the mid-sagittal line, they also will be perpendicular to the para-sagittal line. Consequently, the shoe will be flat on the floor and the joints will be horizontal and parallel to each other as viewed in the frontal plane.

IV. Alignment Considerations in the Transverse Plane

A. *Ankle Joint Axis*—As mentioned on page 111, normal tibial torsion serves to align the anatomical ankle joint so that its motion is compatible with the antero-lateral movement of the center of gravity. If, at any given instant, the ankle axis is not perpendicular to the direction of motion of the center of gravity, compensatory motion in the sub-talar joint will permit movement of the leg on the foot in the direction of the center of gravity.

Since conventional braces do not provide motion corresponding to the sub-talar joint, the correct location of the mechanical ankle axis is of great importance. To achieve this proper location, the mechanical ankle joint must be aligned in accordance with the amount of external rotation of the anatomical joint; that is, with the amount of tibial torsion. This is especially significant when free motion ankle joints are used.

A common error is to relate ankle joint placement in the transverse plane to "toe-out." Toe-out may be defined as the relationship of the long axis of the foot to the line of progression. Normally, the foot exhibits approximately 15 degrees of toe-out. (Figure 1). Moreover, the amount of toe-out may be influenced by several factors other than the normal torsion of the tibia; for example, rotation in the hip or knee joints.

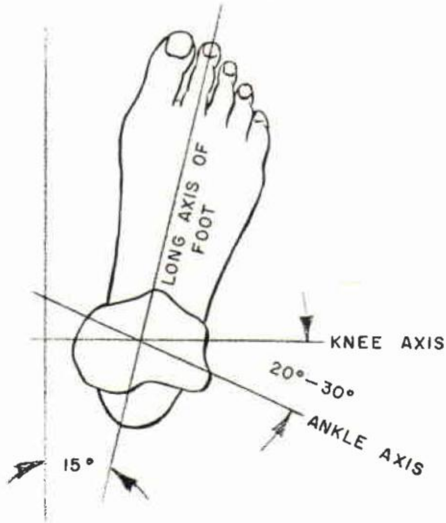

FIGURE 6

Furthermore, the ankle joint axis is normally rotated externally 10 to 15 degrees from a line perpendicular to the long axis of the foot. (Figure 6). Ankle joint placement will be inaccurate, therefore, if it depends solely on the degree of toe-out.

B. *Toe-Out*—Toe-out does not bear a constant relationship to tibial torsion since other factors, such as varus-valgus of the foot, and forefoot abduction-adduction, may influence the degree of toe-out without affecting the position of the ankle axis. The measurement and accommodation of toe-out in orthotics, therefore, must be treated separately from tibial torsion.

V. Effects of Incorrect Brace Alignment

A. *Frontal Plane*—If the shoe and brace joints are not perpendicular to the mid-sagittal reference line, the effects will be as follows:

1. Uneven floor contact resulting in unequal pressure distribution on the foot and possible callus formation. As an example, if the brace is not aligned to accommodate a genu valgum deformity, excessive pressure on the medial surface of the foot may result.

2. Increased wear of the brace joints. Since weight is not transmitted vertically through the joints, sheer stresses and uneven wear of joint surfaces will occur.

3. Lateral instability. If sole and heel surface of the brace shoe is not parallel to the floor.

B. *Transverse Plane*

1. Ankle Joint—If the mechanical ankle joint is rotated internally with respect to the anatomical joint, the effects will be as follows:

a. Pressure concentration on the lateral surface of the foot during gait. Of course, the effect of a misplaced limited motion ankle joint is minimal compared to a free motion ankle joint. This pressure concentration may result in a valgus deformity or forefoot pronation, if there is weakness in the sub-talar or mid-tarsal joints, respectively. Thus, if there is weakness in the sub-talar joint, valgus deformity may result; if there is weakness in the mid-tarsal joints, forefoot pronation may result.

b. Patient fatigue due to binding between anatomical and mechanical ankle joints.

c. Increased wear of brace joints due to torque.

2. Toe-Out—If the patient has more than normal toe-out; that is, about

15 degrees, which is not compensated for in the brace, the effects will be as follows:

a. Sitting discomfort with the long leg brace. The external rotation of the foot will cause a loose fitting brace to rotate externally on the limb. As a result, the mechanical knee joint axis will be rotated externally with respect to the anatomical knee, with ensuing interference and discomfort in sitting.

b. Varus deformity with the long leg brace. With a tight fitting brace, the patient may have to force his foot into varus in order to get his foot into the shoe.

VI. Summary

A primary objective of bracing is to provide the wearer optimum performance with minimum technical assistance and maintenance. This objective can be realized only if the brace is compatible with the alignment of the involved extremity and of the body as a whole.

Three important aspects of providing a brace that meets this criterion as established are the following:

1. The use of the mid-sagittal line as a reference line for brace alignment.
2. The proper placement of the ankle joint axis.
3. The correct accommodation to the patient's foot toe-out.

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ACKNOWLEDGEMENTS

I want to thank Mr. Norman Berger, Mr. Carlton Fillauer, Mr. Warren Springer, and Mr. Bert Titus for reviewing the manuscript and for their helpful suggestions. Mr. Berger's technical and editorial contributions were of particular significance.

I also acknowledge the assistance of the other faculty and staff members of the Prosthetics and Orthotics Division at New York University.

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