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Stiffness control in posterior-type plastic ankle-foot orthoses: effect of ankle trimline
Part 1: a device for measuring ankle moment

T. SUMIYA, Y. SUZUKI and T. KASAHARA

Rosai Rehabilitation Engineering Center, Nagoya, Japan

Abstract

A device was developed to measure the dorsi- and plantar flexion moment of plastic ankle-foot orthoses when deflected. It is operated by manually controlling a lever which is used to apply a nearly static force. Various orthoses can be classified according to the characteristics of the correcting force measured by this device. Simplicity and high reproducibility are the major advantages. However, to obtain measurements approximating the characteristics of orthoses under wearing conditions its use is restricted to orthoses made of low-viscosity materials.

Introduction

Plastic ankle-foot orthoses (AFOs) correct abnormal ankle motion by virtue of their stiffness, which defines their orthotic characteristics (Stills, 1975; 1977). Resistance to manual ankle deflection provides a subjective indication of stiffness. The authors have developed an original device which objectively measures orthotic ankle moment.

Materials and methods

The device consisted of an orthosis-model complex, a pair of metal bars, a tensiometer, a plastic foot enclosure, and a protractor. The orthosis was bent passively with this device and its resistance was an indicator of its stiffness.

A moulded plaster foot and leg model was combined with a plastic AFO so as to permit deformation of orthosis in the same way as when it is worn. The foot model was attached to the frame by a single axis joint at the anatomical ankle axis. The leg model incorporated a pipe which extended from the ankle joint. The foot/leg model was fixed to a plastic AFO with screws and a calf cuff. A vice kept the orthosis-model complex horizontal, so that gravity did not affect the ankle dorsi- or plantar flexion moment.

The 2 metal bars, coupled at the ankle axis, functioned as a lever (Fig. 1). A digital tensiometer was attached to one side bar, so that the loadshaft located on the opposite bar perpendicularly at 0.4 or 0.5m from the axis. This right angled triangle rotated around the ankle axis. When the tensiometer was pulled, the opposite bar pulled the foot through an upright rod in the plastic foot enclosure thus tending to dorsiflex it. The tension force times the lever arm represented the ankle moment applied to the orthosis. A protractor was placed over the metal bars to set the deflection angle at 2.5° intervals (adjustable up to 25°). A screw, which

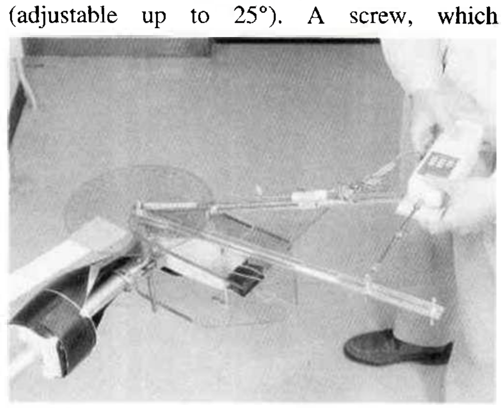

Fig. 1 A whole view of the moment measuring device, during plantar flexing.

All correspondence to be addressed to Tadashi Sumiya, MD, Rosai Rehabilitation Engineering Center, 1-10-5 Komei Minato-ku, Nagoya-shi 455, Japan. Phone: (+81) 52-652-5831 Fax: (+81) 52-652-6275.

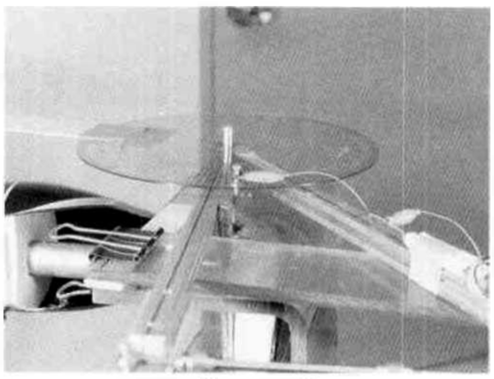

Fig. 2 The touching switch.

penetrated the protractor at 0°, worked as a touch switch (Fig. 2). The opposite bar came in contact with the screw to record the moment value at the preset angle. An experimenter pulled the tensiometer very slowly at an angular velocity of approximately 2°/s so that the opposite bar touched the screw lightly. Thus, the measured value approximated the static moment. The tensiometer had an accuracy of $\pm 0.2\%$.

The hingeless plastic AFO deflected mainly in the postero-inferior region when bent in dorsi- or plantar flexion. This caused the leg model to slide along the pipe proximally in plantar flexion and distally in dorsiflexion. Pipe model-interface friction was minimised by using a lubricant.

The whole device was tested for accuracy by measuring the moment of a polypropylene AFO. The test confirmed measurement reproducibility at 4 force levels, equivalent to 0-5Nm, 5-10Nm, 10-20Nm, and 20-30Nm. One experimenter carried out 100 repetitive measurements at each force level, allowing appropriate intervals for the orthosis to completely recover between measurements.

Results

The maximum moment measured with this device reached 40Nm. This measurable range demonstrated the experimenter's maximum performance, combining force application and velocity control. The lever had to be elongated over 0.5m to apply a moment over 40Nm. The ordinary semi-rigid plastic generated from 30 to 40Nm when plantar flexed 15°.

The ratio of 1 standard deviation to the mean value expressed as a percentage was used as the index of measurement reproducibility. The results were 7.7% at 0-5Nm, 3.9% at 5-10Nm, 2.1% at 10-20Nm, and 1.6% at 20-30Nm level. These low percentages demonstrated the high reproducibility provided by this device.

Discussion

There are no definitive methods for measuring orthotic load/deflection characteristics. The device described has the advantage of being simpler than methods described previously (Robin *et al.*, 1968; Condie and Meadows, 1977: Rubin and Dixon, 1973; Yamamoto *et al.*, 1993a and b; Miyazaki, 1993). It is simply constructed from readily available materials and involves no complicated mechanisms.

The measurements would reflect the characteristics of the orthosis when worn on the body. Plaster models are incapable of accurately reproducing physical softness and ankle motion. However, they do provide consistent experimental conditions, simplifying the contributory factors.

Measurement errors arise from the friction between the pipe and the leg model, the influence of gravity on ankle motion, and with the manual application of force and control of velocity creating the greatest applied error. However, the high reproducibility provided by this device in the repetitive test confirms that the applied errors can be minimized by having the same person perform all the tests paying the utmost attention to the operation. The protractor rotates if the bar hits the screw, which indicates an incorrect measurement.

Plastic AFOs deflect cyclically during ambulation, and produce a dynamic moment accompanied by material fatigue. Ankle angular velocity and the viscosity of the material have a large influence on dynamic moment. However, the device described is not appropriate for dynamic measurements. The indications for this device should be limited to plastic AFOs made of low-viscosity materials (Lipskin, 1971; Showers and Strunk, 1985), including polypropylene, to minimise the discrepancy between experimental and actual use. Furthermore, comparison of the measured moment should be restricted to static or nearly static conditions.

Conclusion

This manually operated device permitted the measurement of orthotic moment with a simple mechanism and provided high reproducibility. Although only approximately static values are measurable, the maximum force range rose to 40Nm with the lever arm length set at 0.5m. The materials of the orthosis should be of low viscosity when this measuring device is used to assess orthotic characteristics during ambulation.

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