*Prosthetics and Orthotics International, 1989, 13, 42–45*

# Measurements of pressure on the sole of the foot in plaster of Paris casts on the lower leg

K. LAURIDSEN, C. G. SØRENSEN,* P. CHRISTIANSEN, I. REIMANN, E. C. JANSEN* and T. K. LARSEN*

*Department of Orthopaedic Surgery T, Herlev Hospital, University of Copenhagen.*

**Biomechanical Laboratory, Department of Orthopaedic Surgery, Gentofte Hospital, University of Copenhagen.*

**Abstract**

Pressure on the sole of the foot inside three different types of plaster cast, used in treatment of fracture of the lower leg, was measured on six normal persons. No significant difference was found between these pressures in below-knee plaster, full length plaster including the thigh and patellar-tendon-bearing plaster. Only occasionally a relief in pressure was found in patellar-tendon-bearing plasters.

## Introduction

Patellar-tendon-bearing (PTB) plaster of Paris cast is often used in the treatment of fracture of the lower leg. From experience gained with the PTB prosthesis it may be assumed that this type of cast is able to transmit considerable axial forces from the knee region onto the cast. Correspondingly a considerable relief of force on the fracture might be assumed.

To test this assumption, measurements were made of pressure between the foot and four types of casts. The four plaster cast types were: a full length plaster including the thigh (FC), a below-knee plaster (BC), a patellar-tendon-bearing plaster (PTB) and a below-ankle plaster — which has no clinical use — (TC).

For this purpose a simple and inexpensive pressure transducer was developed.

## Material and method

Six volunteers were studied, aged twenty to forty, and without disease in the motor system.

By means of an instrumented treadmill, continuous measurements of the foot-to-ground reaction forces could be obtained. The treadmill consisted of two conveyor bands, one for each foot, driven by hydraulic motors and suspended by transducers, making it possible to obtain recordings of the foot-to-ground reaction forces in three directions. Vertical, saggital and transverse force components for each foot were recorded on an analogue tape recorder (Lyrec TR86).

The analogue signals were sent through an A/D converter and processed by an IBM-AT computer, yielding curves of the ground reaction forces describing the average walking cycle.

Two minutes of continuous walking were recorded at each trial, at a constant walking speed of 2 km/h (0.56 m/s). The sampling frequency was 33 Hz (Jansen 1974, Jansen et al. 1982).

The casts FC, BC and PTB were applied as described below. A home-made transducer, shaped as a sole, was installed inside the cast in order to obtain measurements of the pressure applied by the foot onto the sole of the cast. The signals from the sole-transducer were sent through the same recording and computing equipment as mentioned above and recorded simultaneously with the foot-to-ground reaction forces. Continuous curves of the pressure applied to the sole during a walking cycle were

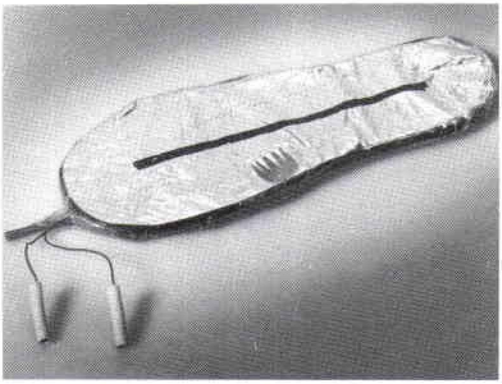

Fig. 1. The transducer-sole consisting of a foot-shaped piece of conductive foam wrapped in aluminium foil.

All correspondence to be addressed to Dr. K. Lauridsen, Department of Orthopaedic Surgery T, Herlev Hospital, DK-2730, Herlev, Denmark.

obtained. The transducer-sole consisted of foot-shaped piece of conductive foam (Conductive Insertion Foam, 3M Company, USA). The material is usually used to wrap sensitive electronic components. The transducer-sole was covered with equally shaped aluminium foil electrodes on both sides. An adhesive plastic wrapping protected the electrodes and foam from moisture (Fig. 1).

The electrical resistance across the foam decreased with increasing compression; thus the sole acted as a resistive transducer.

No zero-level drift could be detected during each test. The relation between the foot-sole pressure and the ground-reaction force was found to be linear (regression coefficient > 0.9 determined at pilot trials). A new sole was used for each subject.

Since the study was designed to compare paired data (each test person was tested with all four types of casts used) no attempts were made to produce exact calibration curves for the transducer-soles used. The values of pressure monitored from within the casts were thus indicated in comparable arbitrary units. Increasing pressure yielded decreasing values (derived from the decreasing resistance of the sole).

Maximum pressure was read from the gait curves at the point of mid-stance. This was defined as the point at which the antero-posterior force shifted from negative to positive values. Gait curves representing two minutes of gait were searched for maximum value at each trial.

Friedman's test was used to compare the slopes of the regression lines at a significance level of $p < 0.05$.

*Procedure*

All four gait tests for each person followed a common scheme. After 2 minutes of adaption to treadmill walking the following 3 minutes of gait were recorded. The speed of gait was 2.0 km/h (0.56 m/s).

First an FC was applied on the right leg of the test person with the transducer-sole interposed between the foot-sole and the cast. A rocker was mounted on the FC and a wooden shoe of convenient height was worn on the left foot. In the second test the cast was cut down to a BC and new measurements performed. In the third test the BC was remodelled to a PTB cast (Fig. 2) and in the fourth the cast was cut down to below ankle level ("tennis-shoe cast") to obtain measurements from the sole and the treadmill when all axial force from the right leg was transmitted through the sole. The casts and the modifications were all made by the same expert orthotist.

Fig. 2. One of the volunteers with PTB plaster of Paris cast on the treadmill during measurement.

**Results**

Graphs of measurements from the transducer-sole, indicated in volts versus vertical force (Newtons) measured during treadmill walking are presented in Figure 3. Regression lines are superimposed. Table 1 shows the maximum sole/cast pressure values read from the gait

Table 1. Maximum force in mid-stance phase, listed in arbitrary units.

| Subject | FC | BC | PTB | TC |
|---|---|---|---|---|
| A | 43.0 | 51.7 | 84.6 | 35.9 |
| B | 55.6 | 53.1 | 50.8 | 42.3 |
| C | 38.3 | 26.5 | 44.8 | 39.3 |
| D | 32.3 | 33.1 | 38.6 | 44.5 |
| E | 38.9 | 48.7 | 111.9 | 46.8 |
| F | 33.9 | 45.2 | 48.6 | 58.1 |

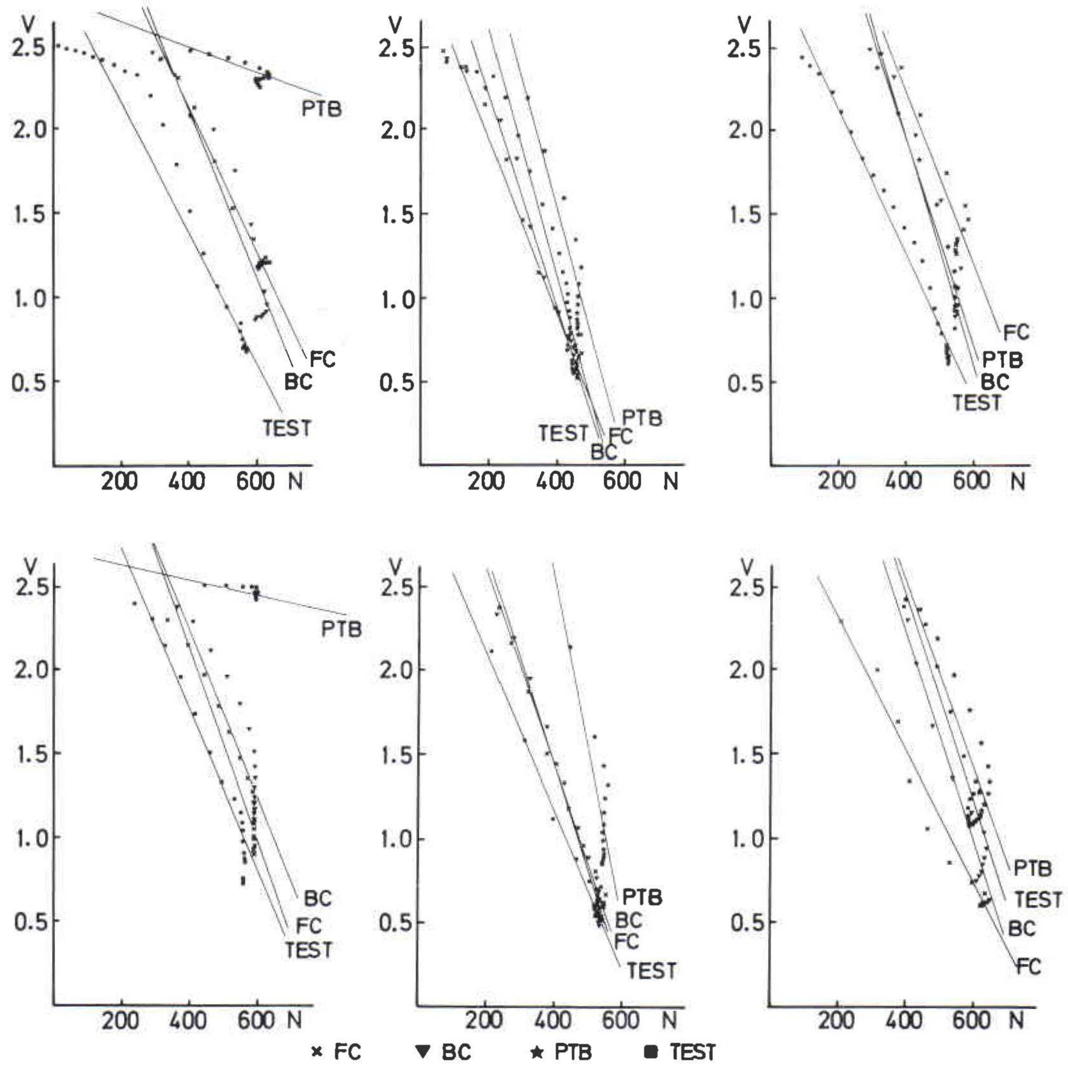


Fig. 3. Graphs of measurements from the transducer-sole, indicated in volts versus vertical force (Newtons), measured during treadmill walking by the six persons investigated with four types of cast.

curves (numeric values were listed on print). Note that increased pressure is indicated by decreased arbitrary units.

Only in two cases is there an obvious relief of pressure on the sole of the foot related to the use of PTB plaster of Paris. The FC did not seem to offer any significant relief in pressure compared to the BC or the "tennis-shoe cast".

No significant difference was found between the slopes of the regression lines from the four types of cast used ($p > 0.05$).

## Discussion

One might think that the FC could relieve some of the axial load from the lower leg, as the muscles of the thigh might act as a plug in the cone-shaped plaster, thus preventing sliding movements of the leg within the cast and some transmission of axial forces. This did not seem to be the case, despite the fact that three of the volunteers had very well developed thigh muscles.

A plaster should protect the fracture site from bending and rotary movements. The bending movements should not be difficult to prevent but rotary stability might be more complicated to ensure. It is not known whether the PTB cast offers as much rotary stability as the FC does.

A certain amount of compression of the fracture site might have a beneficial effect on fracture healing. Letting a patient walk with one of the above-mentioned casts, compression seems to be unavoidable. If one wishes to take some load off the lower leg, achieving this appears to be a matter of chance when using a PTB cast.

## REFERENCES

JANSEN, E. (1974). Computer analysis of gait — preliminary report. Proceedings of the combined meeting of the Danish and Dutch Orthopaedic Associations. Edited by Biermans, A.R.M. et al. Nijmegen: D.D.O.A. pp. 85-87.

JANSEN, E. C., VITTAS, D., HELLBERG, S. & HANSEN, J. (1982). Normal gait of young and old men and women: ground reaction force measurements on a treadmill. *Acta Orthop Scand* **53**, 193-196.