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Equipment and methods for laboratory testing of ankle-foot prostheses as exemplified by the Jaipur foot

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Editor's Note:

The following comments, made by one of the peer reviewers of this manuscript, are presented in order to assist the reader in placing the importance of this work in its full perspective.

This paper has tremendous value because of its description of meaningful technical work done at low cost with simple, readily available equipment much like the initial VA-sponsored work on the SEATTLE FOOT®. This kind of test equipment might be considered for review by the on-going International Standards Committee (ISO) with which I participate.

Donald L. Poggi, Chairman
Model & Instrument Development
Seattle, Washington

Abstract—A load deflection and a cyclic loading apparatus capable of measuring dorsiflexion/plantarflexion, pronation/supination, internal/external rotation, and cyclic dorsiflexion (60 cycles per minute) of ankle-foot prostheses are described. A test protocol was developed to assess the functional parameters of the Jaipur ankle-foot prosthesis before and after prolonged cyclic loading, with the simultaneous aim of evaluating these machines. The results on 26 Jaipur ankle-foot prostheses revealed that: 1) the prosthesis enjoys considerable mobility in three planes, confirming its known versatility; 2) the prosthesis is robust; and, 3) the testing machines deliver reproducible results and are suitable for in-house testing of ankle-foot prostheses.

Key words: *ankle-foot prostheses, biomechanics, Jaipur foot, lower limb amputees, safety and testing equipment, standards and specifications.*

INTRODUCTION

The Jaipur ankle-foot prosthesis (Jaipur foot) (2,4) provides for movement in three planes, *vis-a-vis* dorsiflexion and plantar flexion; pronation and supination; and transverse rotation at the ankle, thus corresponding to a Department of Veterans Affairs Class III prosthesis, series 6130 (5). The prosthesis is hand-fabricated using locally available raw materials of variable quality and fitted on the amputee without prior bench-testing. In practice, the wide safety margins inherent in the design and fabrication methodology

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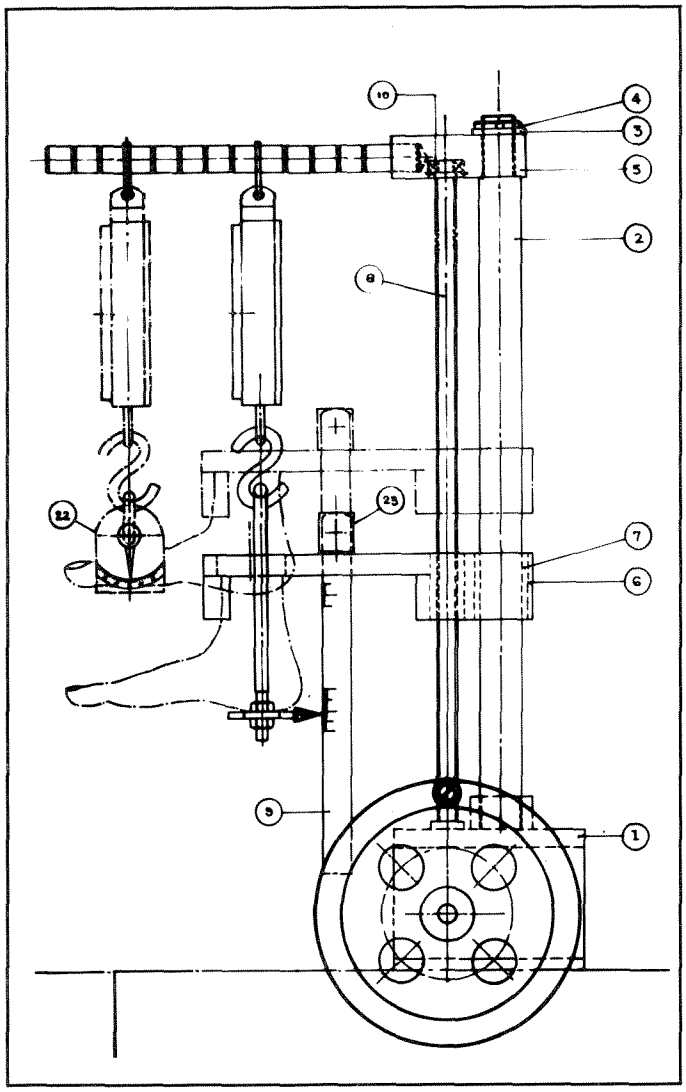

Figure 1.
Engineering drawing of the load deflection apparatus: Side view. 1=base; 2=column; 3=washer; 4=nut; 5=cantilever; 6=sliding bracket; 7=bush; 8=thread shaft; 9=steel scale 25 cm; 10=ball bearing.

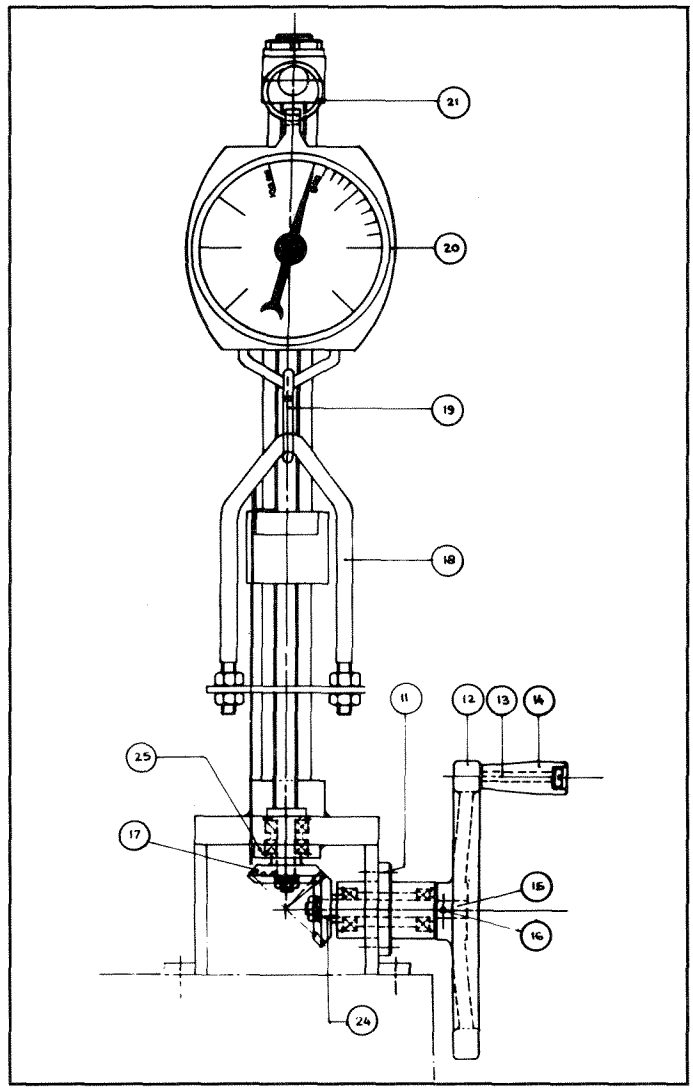

Figure 2.
Engineering drawing of the load deflection apparatus: Front view. 11=BRG housing; 12=handwheel; 13=screw; 14=handle; 15=shaft; 16=locking pin; 17=bevel gear; 18=heel compression stirrup; 19=link; 20=spring balance; 21=ring; 22=dorsiflexion stirrup with goniometer on the side-arm; 23=bracket; 24=key; 25=external circlip. Note: The dorsiflexion stirrup shown in the drawing was replaced by a nylon sling and a universal goniometer.

of the prosthesis adequately compensate for all but gross variations in materials or construction; therefore, the need for bench-testing was never considered necessary. Yet, objective laboratory evaluation is required if the foot is to be compared with other prostheses, modified in any way, functionally analyzed, or simply standardized for reference purposes. To enable such evaluation to be carried out, we have developed protocols using locally designed and fabricated testing equipment.

MATERIALS AND METHODS

The following functional attributes of the Jaipur foot were studied using the indigenously developed load deflection and cyclic loading apparatuses:

1. Dorsal deflection on incremental loading
2. Compression of the heel on incremental pressure
3. Upward deflection of the lateral border (supination) on incremental loading
4. Upward deflection of the medial border (pronation) on incremental loading
5. Axial rotation (of the foot on the ankle block) on incremental loading
6. Parameters 1 and 2 after prolonged, simulated fatigue.

Load deflection apparatus

In **Figure 1** and **Figure 2**, the load deflection apparatus measures linear or angular deflection consequent to controlled, incremental loading. It consists of a spring balance suspended from a cantilever attached to a vertical steel column. A sliding bracket rides over the column. Attached to the sliding bracket is a lever arm that has two clamping devices at its free end which hold the prosthesis vertically or horizontally. A thread shaft runs through a nut incorporated in the sliding bracket. The thread shaft is rotated through a beveled gear system operated by a handwheel. By rotating the thread shaft, the sliding bracket can be made to slide up or down, carrying the clamped prosthesis with it.

Heel compression (**Figures 1, 3,** and **4**), dorsiflexion (**Figures 1, 5,** and **6**), pronation (**Figures 7** and **8**), supination (**Figures 9** and **10**), and axial torsion (**Figures 11, 12, 13,** and **14**) are effected by loading the foot appropriately against resistance. This is achieved by moving the clamping bracket, thereby moving the foot against a stirrup or sling that passes around the foot and connects to a spring balance. As the foot pulls on the stirrup or sling, a reading of the magnitude of the net acting force can be obtained from the spring balance. Dorsal deflection, supination, pronation, and ankle torsion consequent to the applied force are measured in angular terms (degrees) by means of a goniometer that is attached to an appropriate part of the foot. To measure heel compression, a horizontal pointer is fixed to a metal stirrup that compresses the heel as the foot is moved down. The ensuing compression is measured in linear terms (millimeters) on a fixed, vertical scale (**Figure 1, 3**). Except for heel compression, we have preferred using a nylon sling rather than a metal stirrup because the latter tends to slip off a deformed foot. For evaluating pronation and supination, the nylon sling is passed around the foot, through the ring at its other end, and suspended from the spring balance (**Figure 7** and **Figure 9**).

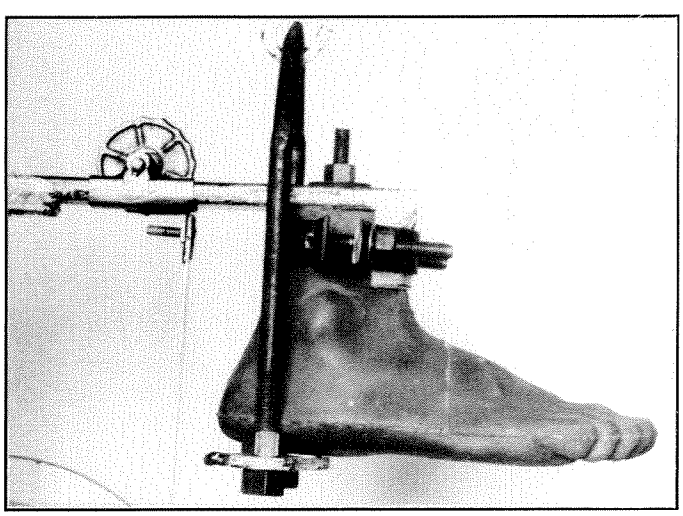

Figure 3.
Heel compression stirrup in use.

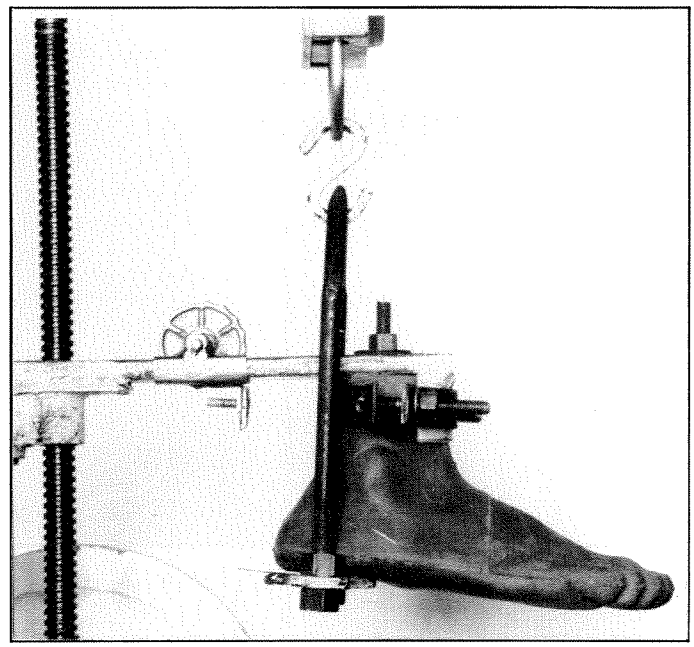

Figure 4.
Heel compression stirrup in use.
Note the true plantar flexion on loading the heel.

The universal goniometer consists of an ordinary plastic protractor screwed to the shorter, rectangular flange of a modified metal hinge (**Figure 15**). The longer flange of the hinge is fixed horizontally onto the foot being tested so that the shorter flange and the protractor are vertically disposed. Fixation to the goniometer to measure supination or pronation is effected by passing the longer limb of the hinge between the sole of the foot and the sling so that it is in line with the second toe (**Figure 7** and **Figure 9**). When the sling is rendered taut, it holds the goniometer firmly in place. For measuring dorsiflexion and ankle torsion, the goniometer is fixed to an appropriate part of the foot by means of a screw clamp (**Figures 5, 11,** and **13**). The freely swinging protractor compensates for other incidental movements that occur in another plane. A freely swinging plumb line is suspended from the center of the protractor. The protractor is adjusted so that its center is dead horizontal (the plumb line passes through the 90 degree mark), and the screw holding it to the flange is tightened.

Methods of measurement

a. Heel compression (Figure 3 and Figure 4)

The spring balance is slid back on the cantilever to rest directly above the heel. The heel compression-

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measuring stirrup is suspended from the spring balance and slid over the foot until its foot piece rests under the heel. By rotating the handwheel, the sliding bracket is brought down until the heel of the prosthesis makes contact with the foot piece. A reading is taken of the position of the pointer on the scale. The sliding bracket is further brought down until the spring balance reads 10 kg. A reading is taken of the position of the pointer on the scale. The steps are repeated at 10 kg increments until a maximum of 70 kg is reached.

b. Dorsiflexion (Figure 5 and Figure 6)

The spring balance is slid over the cantilever to rest in a slot directly over the forefoot. The nylon dorsiflexion sling is suspended from the spring balance and slid over the forefoot; the goniometer is clamped onto the medial border of the great toe. By manipulating the handwheel, the foot-plate of the stirrup or the sling is engaged with the forefoot and the spring balance is set to zero.

The sliding bracket is lowered until the spring balance reads 10 kg. The ensuing deflection of the foot is read from the goniometer. The process is repeated for load increments of 10 kg until 70 kg is reached.

c. Pronation and supination (Figures 7 through 10)

The dorsiflexion stirrup is now replaced with the pronation/supination measuring sling. For pronation, the sling is adjusted so that it pulls on the lateral border of the foot (**Figure 7** and **Figure 8**); for supination it is adjusted so that it pulls on the medial border (**Figure 9** and **Figure 10**). The goniometer is placed in position under the sole. By manipulating the handwheel, the load applied is increased stepwise by 10 kg until a total of 40 kg is reached and the corresponding angular deflection of the forefoot is measured on the goniometer.

d. Axial torsion (Figures 11 through 14)

This process is similar to the one used in studying load deflection for dorsiflexion except that the foot is clamped in a horizontal position with either its medial or lateral border facing upward. The medial or lateral torsion is measured on the goniometer clamped to the great toe. Load increments of 10 kg are applied up to a maximum of 40 kg; the angular deflection is read at each step.

Cyclic loading apparatus

The cyclic loading apparatus which simulates continuous use is utilized for fatigue studies (**Figure 16** and **Figure 17**). As in the load deflection equipment, the cyclic loading apparatus has a sliding bracket which rides over a vertical steel column. A thread shaft runs through a nut incorporated in the sliding bracket; the shaft is rotated

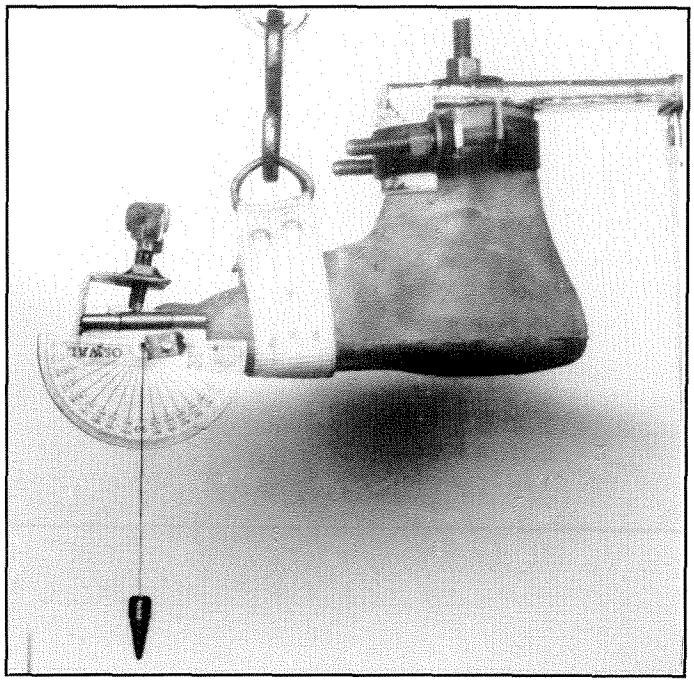

Figure 5.
Dorsiflexion nylon sling and the universal goniometer in use.

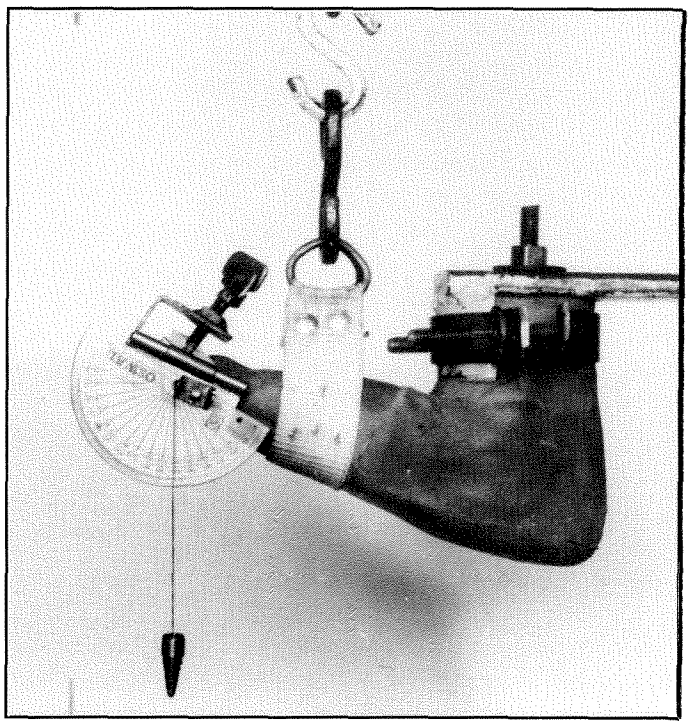

Figure 6.
Dorsiflexion nylon sling and the universal goniometer in use. The goniometer is attached by the clamp to the medial border of the great toe. Note the plumb line recording the deflection when the forefoot is loaded. Also note that the posterior border of the prosthesis is straightened as the heel rolls forward with dorsiflexion.

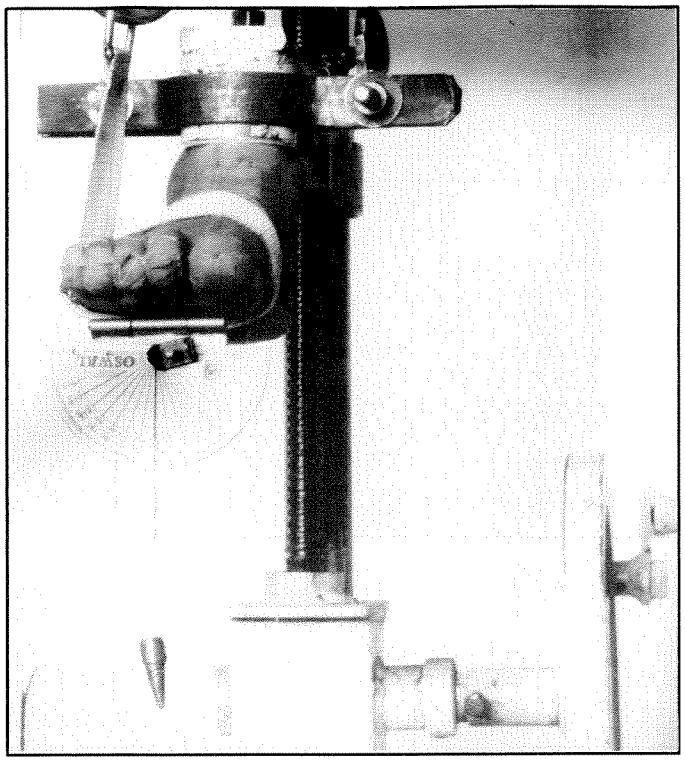

Figure 7.
The pronation nylon loop in use.

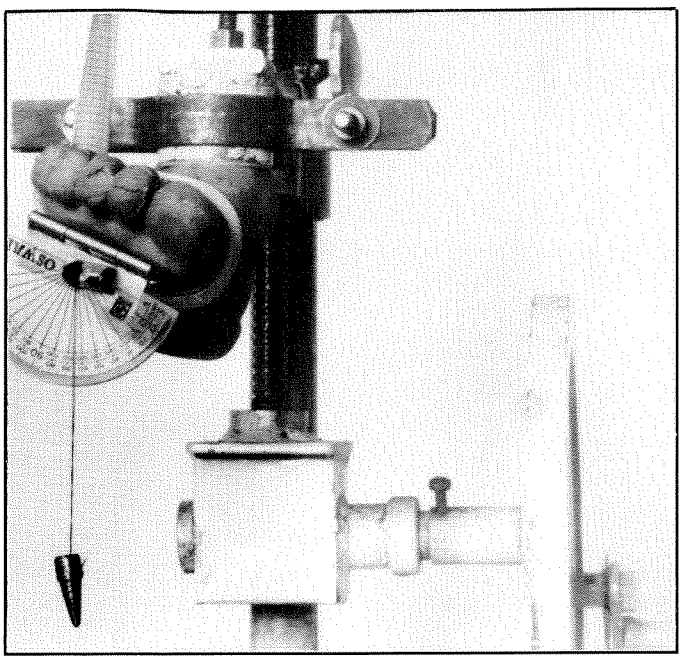

Figure 8.
The pronation nylon loop in use.
The goniometer is attached to the sole. The freely swinging hinge of the goniometer neutralizes the effect of concomitant dorsiflexion that occurs with pronation and supination. Note the closed loop nature of the sling which ensures that the selected border of the foot is loaded.

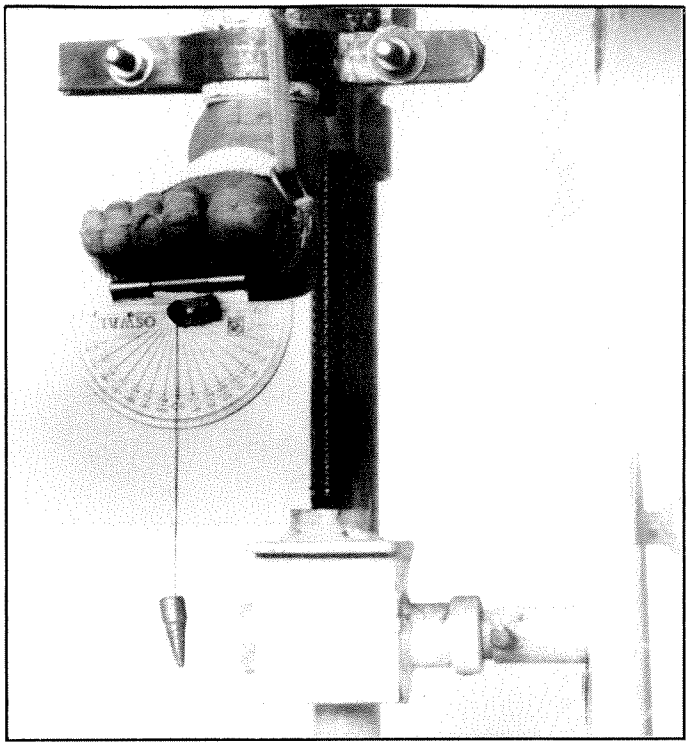

Figure 9.
Supination nylon loop in use with the goniometer in place.

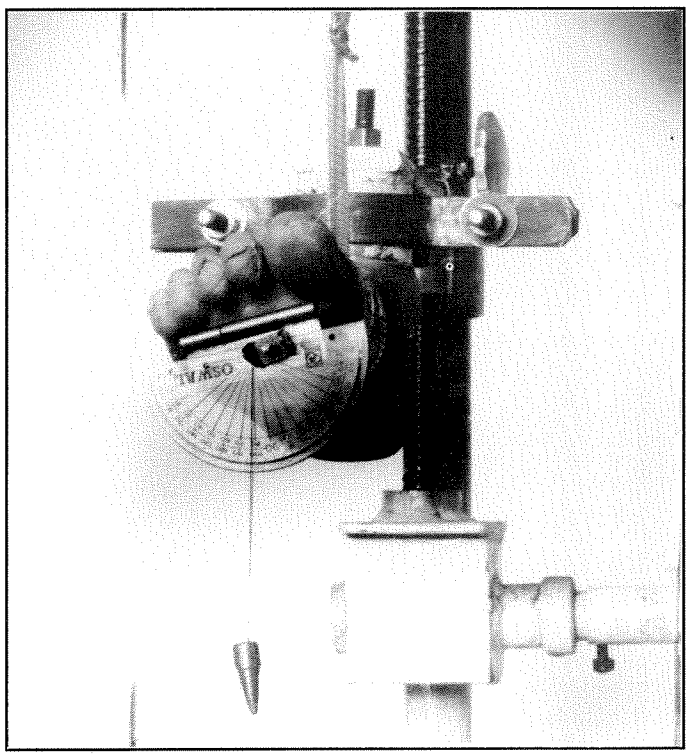

Figure 10.
Supination nylon loop in use with the goniometer in place.

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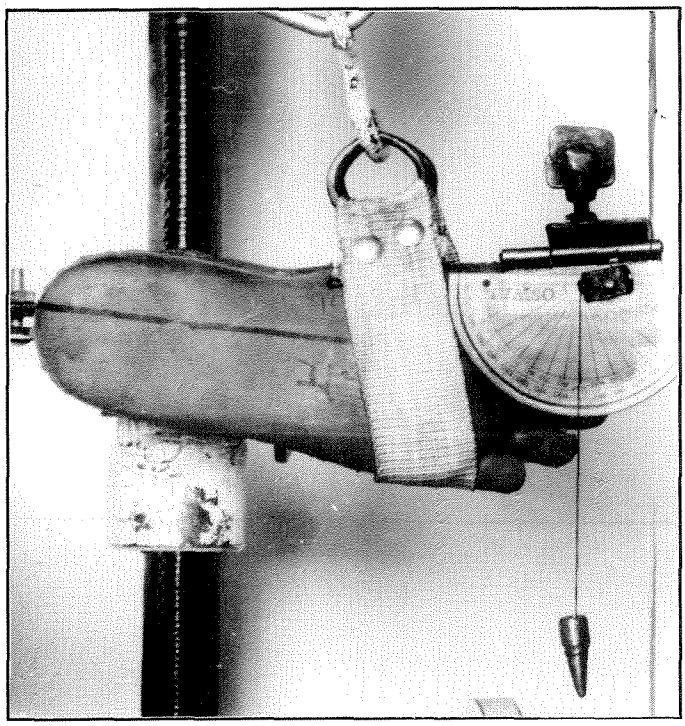

Figure 11.
Internal rotation. The prosthesis is held horizontally by a suitably modified clamping device. The same nylon sling used for dorsiflexion is used here.

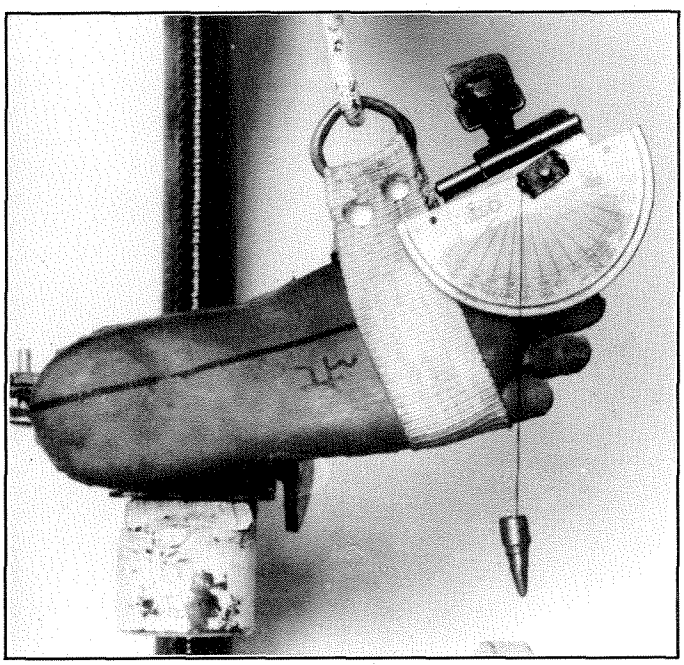

Figure 12.
Internal rotation. The goniometer shows the recorded internal rotation. The foot piece used is experimental with only one strap of tire cord running anteroposteriorly across the sole. The restraining side straps on either side of the ankle were not incorporated in this prosthesis; hence, the movement is greater than that normally seen.

through a beveled gear system which is operated by a handwheel.

A lever arm with a prosthesis clamping device at its free end is attached to the sliding bracket. The lever arm tilts downward at 20 degrees. Thus, the sole of an ankle-foot prosthesis held in a clamp makes an angle of 20 degrees with the horizontal plane.

A horizontal plate is fixed below the foot clamp. The plate is hinged, works like a rocking platform, and is lifted periodically through a distance of 2.5 cm by a rotating cam driven through a belt-pulley system by a motor. A reduction gear is effected so that the plate is lifted by the cam 60 times a minute. The plate, as it lifts, dorsiflexes the fixed foot and simulates forefoot loading. The cam has a ball bearing ring to avoid friction with the plate.

Method of measurement

Figure 18 and **Figure 19** show the ankle-foot prosthesis in the clamping device. The cam is rotated by hand in order to set the rocking plate at its highest position. By means of the handwheel, the sliding bracket is lowered until the toes of the prosthesis make contact with the plate. The cam is rotated to lower the plate. The foot is lowered further by approximately 2.5 cm to a desired distance, depending on the degree of forefoot dorsiflexion required, and is locked in position.

The motor is switched on and allowed to run in order to subject the prosthesis to cyclic dorsiflexion for a stipulated number of cycles. In prolonged testing, after 10 to 12 hours of continuous operation, the motor is stopped for 30 minutes to prevent overheating. If each cycle is deemed equivalent to one complete stride measuring one meter, then 3 million cycles are equivalent to about 3 years of regular personal use of the foot by an amputee.

When the determined period of cyclic loading is complete, the foot is allowed to cool down for 30 minutes before its functional parameters are reassessed. Comparison of pre- and postcyclic loading parameters is then carried out to determine any functional deterioration of the foot consequent to prolonged cyclic loading. A significant deviation from pre-cyclic values indicates deterioration in the respective parameter and may help in predicting prosthetic fatigue and failure. This test may be performed on all feet as a product assurance test, or random or selected foot pieces may be tested for fatigue failure by continuous cyclic loading for 500,000 or 3 million cycles (to correspond to 3 years of regular use by an amputee).

Direction of force

When the foot is horizontal, the direction of application of force is perpendicular to the foot, but as the foot deforms, that is no longer so. The force that is actually

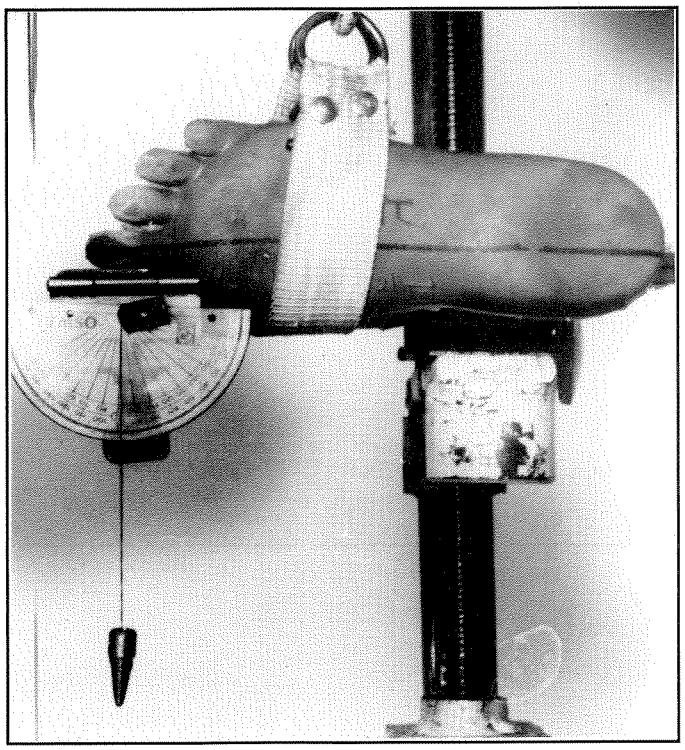

Figure 13.
External rotation.

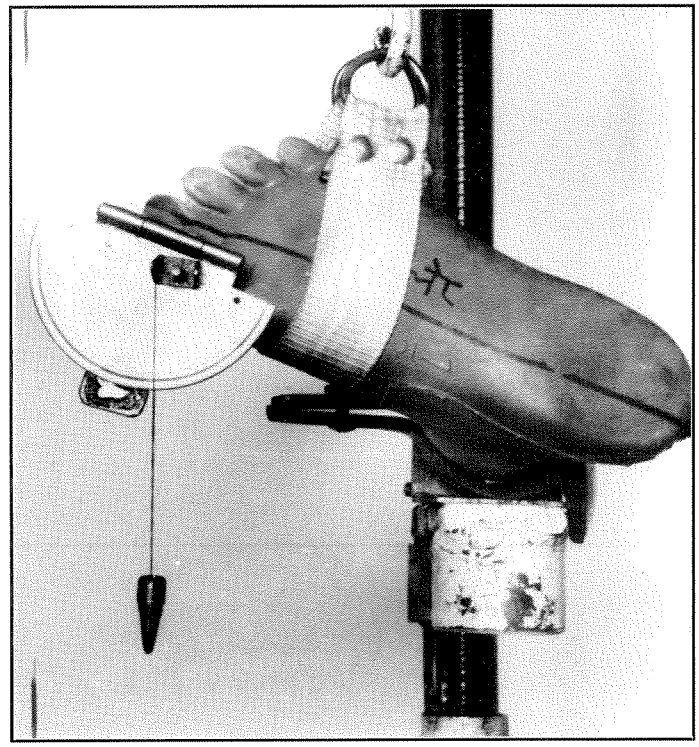

Figure 14.
External rotation.

deforming the foot is now a component of the force that is read off the spring balance, and may be calculated using the law of parallelogram of forces as follows:

Force=load (take reading from spring balance) × cos Θ, where Θ is the angle of deflection.

Torque

It is probable that torque (load × length of moment arm) may be preferred to load alone while considering forces acting on the foot.

We have, however, chosen to express the force in terms of load alone for the following reasons:

1. The axes are not well defined or accurately located. The axes are not stationary and tend to shift with sequential loading (e.g., rolling forward of the heel in dorsiflexion and conjunct dorsiflexion with pronation and supination).

2. The exact point of force is difficult to calculate because it tends to be spread over the width of the nylon sling, especially when the foot is more horizontal.

3. The data generated are meant for in-house comparative testing and not for physical characterization of the prosthesis. For this purpose, the parameters expressed as load versus deflection are easier for the foot fabricator and the workshop supervisor to understand and follow.

An estimate of the axis point can be arrived at by repeated load-deflection curves using different points for application of load, or by using reference lines. We have estimated the axes to be located as follows: 1) for dorsiflexion—passing transversely through the midheel; 2) for axial rotation—passing vertically through the center of the ankle block; and, 3) for pronation/supination—passing longitudinally through the second toe. The actual distances may be measured off the foot and will vary depending on the size of the foot (see footnotes: Table 1, 3). Using these distances, torque (in newton meters) can be calculated as: Torque=Load (kg)×cos Θ×distance (meters)×9.8 (where Θ=angle of deflection from the earlier force, and 9.8=gravitational constant).

In total, 26 Jaipur foot pieces of various sizes, consecutively prepared at our center, were tested with the load deflection and cyclic loading apparatuses. All 26 were tested for dorsiflexion and heel compression and 8 for pronation, supination, and ankle torsion. One size 7 foot was reevaluated (dorsiflexion and heel compression) after 3 million cycles on the cyclic loading apparatus, and one each of sizes 7 and 8, were similarly reevaluated after 500,000 cycles. Results were analyzed by the *t*-test.

RESULTS

The results reveal that the Jaipur foot enjoys flexibility in several planes. In the sagittal plane, it is capable of 22 degrees to 37 degrees dorsal deflection (dorsiflexion

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Table 1.
Load versus dorsal deflection (dorsiflexion).

Load in kg	10	20	30	40	50	60	70
Foot size, Side Mean wt. + SD (No. of feet)	**Deflection (Degrees + SD)**						
6L/735.8 (2 feet)	3.5	7.0	10.0	13.5	17.0	20.0	26.5
6R/642.0 (2 feet)	2.5	5.0	8.0	11.5	15.0	18.5	22.5
7L/895+60.4 (11 feet)	2.7 +0.8	6.3 +1.2	10.3 +1.8	14.9 +2.1	19.9 +3.2	24.9 +4.1	30.0 +4.8
7R/864+30.6 (4 feet)	5.7 +0.9	9.7 +0.5	14.5 +1.7	21.0 +5.1	26.7 +6.0	31.7 +6.0	36.7 +6.4
8R/813.7+6.0 (3 feet)	4.0 +1.7	7.7 +2.1	12.3 +2.3	16.6 +2.1	21.0 +2.0	25.6 +2.1	29.3 +2.5
9L/944.5+5.9 (4 feet)	2.2 +0.9	6.5 +2.5	11.5 +4.4	17.5 +5.7	23.5 +8.1	28.7 +9.3	34.7 +11.5

Note: As an aid to assist in calculating torque, the foot sizes are as follows:

	Heel to toe (cm)	*mid heel to toe break (cm)*	*Width at toe break (cm)*
Size 6	21	12.0	8.5
Size 7	22	12.5	9.0
Size 8	23	13.0	9.5
Size 9	24	13.5	10.0

For dorsiflexion and ankle torsion, the midheel to toe break distance is used as the best estimate of the length of the moment arm, since the level of the axes in either case is midheel.

For pronation/supination, the best-guess axis is a longitudinal line passing through the second toe. The distance from the point of application of the force to the axis for both supination and pronation is = (width at toe break)/2 since this line passes through the mid point of the breadth of the foot at the toe-break level.

Table 2.
Load versus heel compression.

Load in kg	10	20	30	40	50	60	70
Foot size, Side Mean wt. + SD (No. of feet)	**Compression (mm + SD)**						
6L/735.8 (2 feet)	2.0	3.5	4.5	5.5	7.0	8.5	9.5
6R/642.0 (2 feet)	2.5	4.0	5.0	6.0	7.5	10.0	11.5
7L/895+60.4 (11 feet)	2.7 +1.4	3.9 +1.5	5.2 +1.7	6.6 +1.8	8.0 +1.9	9.5 +2.2	11.2 +2.0
7R/864+30.6 (4 feet)	4.2 +2.5	6.2 +3.3	8.7 +3.8	10.7 +3.6	13.0 +4.4	14.7 +4.0	17.0 +4.9
8R/813.7+6.0 (3 feet)	4.0 +1.7	7.6 +2.1	12.3 +2.3	16.6 +2.1	21.0 +2.0	25.6 +2.1	29.3 +2.5
9L/944.5+5.9 (4 feet)	1.0 +1.0	2.0 +1.7	3.3 +2.1	4.6 +2.5	6.0 +2.6	8.0 +2.6	10.6 +2.5

plus toe extension) from the horizontal when the forefoot is loaded to 70 kg (**Table 1**). The deflection is load dependent and varies directly with the load (**Figure 20**). The load deflection parameters, for a given size produced from the same mold, are uniform with a narrow intragroup variation. The peak deflection at 70 kg was not significantly different for extreme foot sizes (6 and 9) in this study ($p > 0.05$). Dorsiflexion was associated with the rolling forward of the heel (**Figure 5** and **Figure 6**). The heel of the Jaipur foot is compressible by 1 to 3 cm at a peak load of 70 kg (**Table 2**). The compressibility is uniformly load dependent (**Figure 21**). There is however, considerable intragroup variation in the majority of foot sizes. The peak compressibility is not size or weight dependent. When the heel was compressed, simultaneous plantar flexion of the

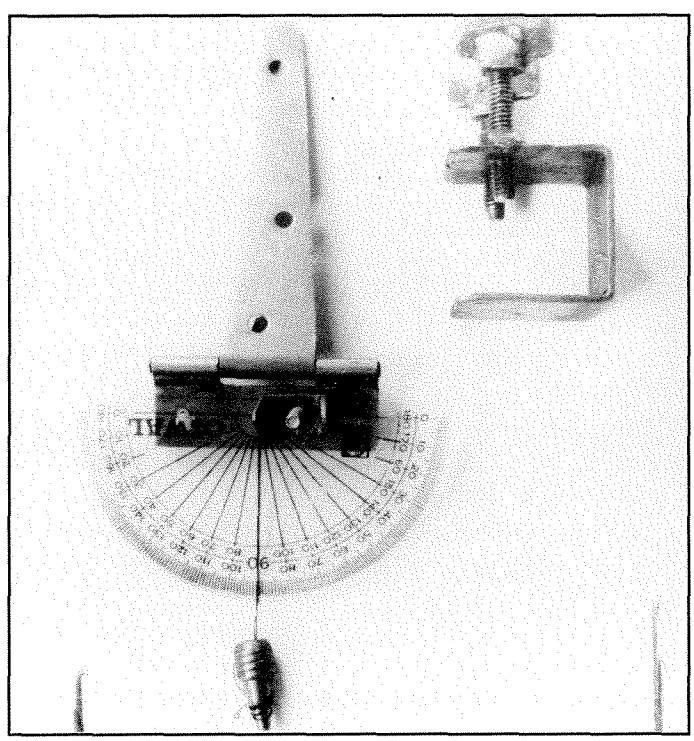

Figure 15.
Goniometer and clamp. The protractor is fixed to one flange of the hinge with a flying nut. (The hinge has a long and a short flange.) By loosening the nut, the baseline can be adjusted to dead horizontal with reference to the plumb line (90 degrees).

forefoot occurred (**Figure 3** and **Figure 4**). The Jaipur foot is capable of 26-29 degrees of pronation and 17-22 degrees of supination at a peak load of 40 kg (**Table 3**). An internal rotation of 10-12 degrees and an external rotation of 4-8 degrees was obtained at a peak load of 40 kg in this study (**Table 3**).

Retesting for dorsiflexion and heel compression on two foot pieces after 500,000 cycles and on one after 3 million cycles of loading yielded similar results, proving that no deterioration occurred in the tested feet after simulated fatigue.

Throughout this study, there were no major problems associated with either apparatus, other than occasional slippage or fraying of a belt in the cyclic loading apparatus. These were easily rectified by realigning the involved pulleys. After 3 million cycles, the sole of the tested foot showed even abrasion, but this was negligible. The results were reproducible when repeated on the same foot piece. Independent observers obtained similar results, confirming such reproducibility.

Table 3.
Load versus torsional displacement.

Load in kg		**10**	**20**	**30**	**40**
Size-side/ Wt in Gm + SD (No. of feet)	**Torsional Rotation tested**	**Deflection (Degrees + SD)**			
7L/828.3+7.6 (4)	Int	3.0 +2.5	6.2 +3.8	8.0 +2.9	10.5 +3.4
	Ext	2.0 +0.0	3.0 +1.0	4.5 +0.7	4.5 +0.7
	Pro	9.5 +2.1	10.2 +2.9	20.7 +2.6	26.5 +3.3
	Sup	6.2 +1.7	11.7 +2.2	15.0 +2.7	17.7 +2.5
7R/835 (2)	Int	3.5	8.0	10.0	11.5
	Ext*	4.0	6.0	7.0	8.0
	Pro	10.5	17.0	23.5	29.0
	Sup	12.5	16.5	19.0	22.0
8R/870* (1)	Int	5.0	9.0	11.0	12.0
	Ext	4.0	6.0	7.0	8.0
	Pro	13.0	20.0	24.0	29.0
	Sup	10.0	15.0	19.0	21.0
9L/938* (1)	Int	2.0	6.0	8.0	10.0
	Ext	1.0	3.0	3.0	4.0
	Pro	11.0	19.0	21.0	27.0
	Sup	9.0	15.0	18.0	21.0

Int=Internal rotation; Ext=External Rotation; Pro=Pronation; Sup=Supination.
*Only one foot tested.
Calculation of torque: see footnote, Table 1.

DISCUSSION

The types of testing equipment which we described are valuable aids in foot fabrication workshops in which they can be used for quality assurance, standardization, and comparison studies. They were designed and fabricated in our hospital workshop according to test schemes developed in consultation with our foot fabricators and prosthetists. Their useful modifications regarding the clamping and measuring devices and the substitution of a nylon sling for the metal stirrup were incorporated.

The equipment was fabricated by mechanics with no formal training but who learned their skills through apprenticeship. No engineering drawings were used, proving that such machines can be developed in modest workshops. The drawings themselves were prepared much later by a professional draftsman and were based on the equipment already fabricated. The only purpose of these drawings is to allow these apparatuses to be duplicated at other centers. At $40 and $180 respectively, including labor, both the load deflection and the cyclic loading equipment were remarkably inexpensive. Yet, despite their low cost and simple construction, our studies prove that these machines are capable of yielding meaningful, reproducible results. Until now, testing of ankle-foot prostheses has been limited by the cost and complexity of available machines, restricting their use to centers which produce these prostheses on a mass scale, or to specialized research institutions. The apparatuses described in this study are meant to fill this gap. They can be utilized by small workshops in the developing world countries and will be valuable in maintaining in-house standards. Testing is so easy and quick that virtually all foot pieces fabricated at a small center can be screened quickly for gross defects by suitable modifications of the protocol we have described.

The force deflection apparatus is capable of estimating hysteresis in prosthetic feet, and we have used it for that purpose. However, we have chosen not to report our figures because loading and unloading were stepwise and gross.

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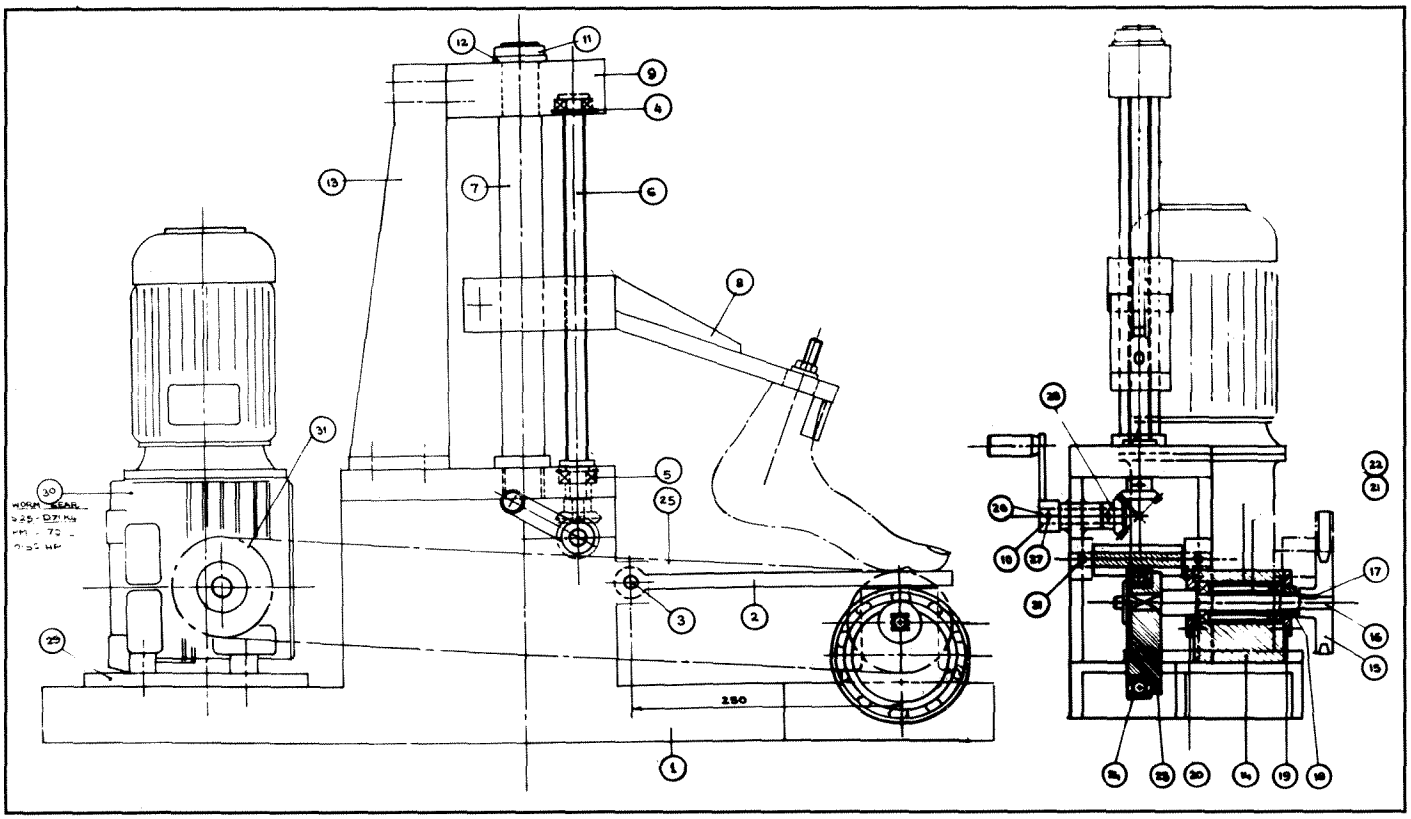
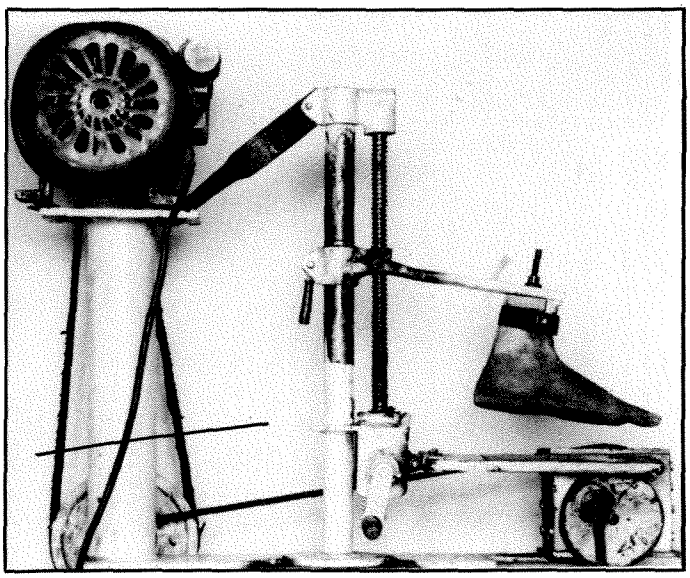


Figure 16./Figure 17.
Cyclic loading apparatus. 1=base; 2=flap; 3=pin; 4=internal circlip; 5=ball bearing 115 PP; 6=thread shaft, 7=column; 8=sliding bracket; 9=bracket; 10=handwheel; 11=nut; 12=washer; 13=support bracket; 14=BRG housing; 15=pulley; 16=shaft; 17=key; 18=nut; 19=end cover; 20=end cover; 21=spacer sleeve; 22=spacer sleeve; 23=cam; 24=ball bearing; 25=V belt; 26=shaft; 27=pin 30×30 LG; 28=bevel gear; 29=base plate; 30=gear box; 31=pulley.



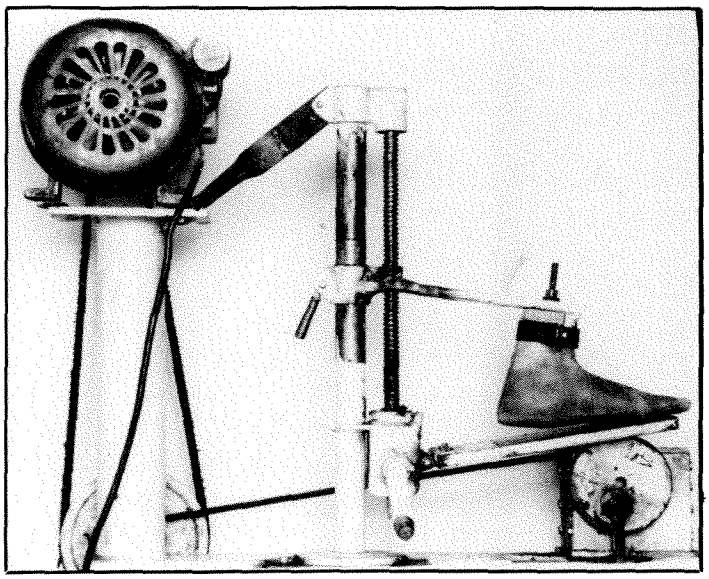


Figure 18. **Figure 19.**
Cyclic loading apparatus in use. An earlier version where gear reduction is by a system of pulleys. The cam in this machine does not carry a ball bearing ring to reduce friction.

Characteristics of the Jaipur foot

The results confirm that the Jaipur foot enjoys flexibility in several planes. Although this fact was known earlier and was responsible for the success of the prosthesis, a comprehensive, objective appraisal of the foot has not, so far, been reported. Detailed but limited studies on the functional and structural aspects of the Jaipur foot have been carried out in the past but these have been in the nature of research projects with no immediate practical bearing (3).

The flexibility (deformability) of the Jaipur foot is proportional to the degree of loading and accrues from: 1) the variable density of the rubber core blocks; 2) interaction at the ankle block (of wood)/heel block (of compressible rubber) interface; and, 3) the quality and thickness of the external rubber shell. The direction, width, and number of layers of the tire cord strips appear to restrain and modulate flexibility in various directions, thereby simulating fascial, muscular, and tendinous modulators in the living foot. Because the individual prosthesis is hand-fabricated, the fabricator can modify a desired functional attribute of the prosthesis by altering either the hardness of the inner core, or the orientation, pattern, and number of layers of the tire cord straps at a desired site in the external shell.

Unlike the SACH foot (1), heel compression in the Jaipur foot is associated with true plantar flexion (**Figure 3** and **Figure 4**) and dorsiflexion is associated with the rolling forward of the heel (**Figure 5** and **Figure 6**) because of the modulating effect of the tire cords. Although the Jaipur foot is not prepared with varying heel compressibilities, such modifications are possible. The Jaipur foot is capable of pronation and supination (always associated with dorsiflexion), and torsion in a transverse plane around a vertical axis passing through the ankle.

Demonstrable functional variations within each group are clearly seen and even the weights of foot pieces of similar size and side vary. The small numbers within each group preclude statistical analysis but it is reasonable to assume that these differences arose because the foot is hand-fabricated and the dies are not uniform even for a given size or side. However, the extraordinary design of the foot and its capacity to function usefully despite lack of standardization, mean that its design inherently possesses a wide margin of safety. Testing equipment such as ours should help reduce the magnitude of even these marginal variations.

Reassessment of dorsiflexion and heel compression after subjecting the foot to prolonged (3 million cycles) dorsiflexion revealed no deterioration in the functional

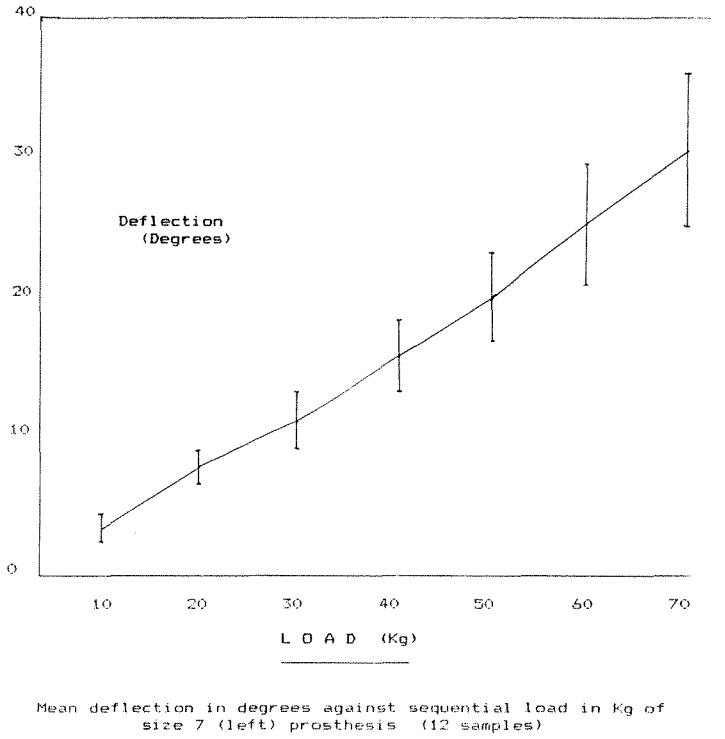


Figure 20.
Dorsiflexion on incremental loading of the forefoot.

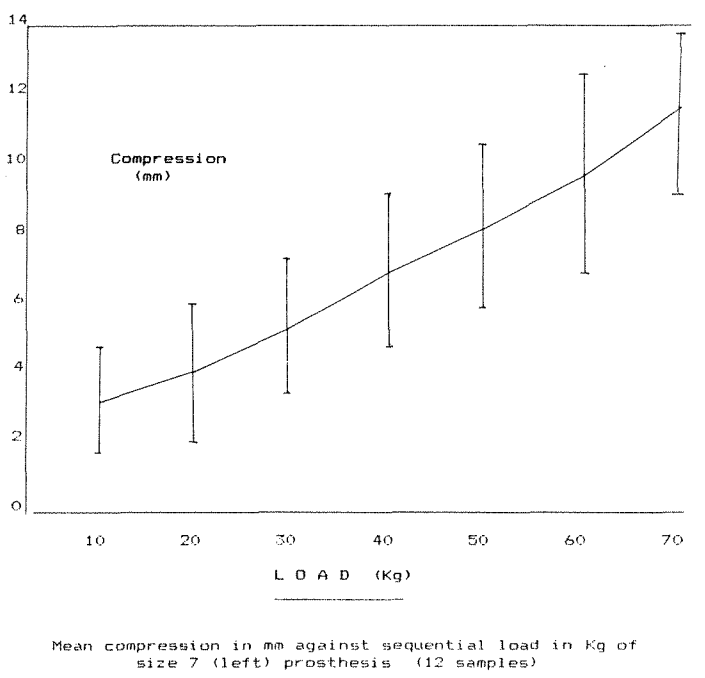


Figure 21.
Heel compression on incremental compression of heel.

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attributes, and the only noticeable structural change was the thinning of the sole-plate. Admittedly, the cyclic loading machine does not faithfully reproduce the varied (and often difficult) terrain that the foot would be subjected to with real use. Nevertheless, because the study simulates 3 years of use, the results suggest that the foot is robust.

The philosophy of using locally available materials, being central to the very concept of the Jaipur foot, has been extended to the testing machines. We feel that these machines should be used personally by the fabricator in order to assess his product and make any necessary changes.

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