MODERN SPLINTING BANDAGES

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We have assessed the current range of synthetic splinting bandages, using physical and mechanical tests and the subjective opinions of patients, volunteers and orthopaedic staff. Modern bandages have some better properties than standard plaster bandage but do not conform as well, are more expensive, and potentially more hazardous.

Plaster of Paris (POP) bandage is the most widely used orthopaedic splinting material, mainly because of its good moulding properties and low cost. However, it has a number of disadvantages: its poor mechanical and radiographic properties, long curing time and messy application have stimulated research for a better alternative.

Modern splinting bandages rely on a polyurethane (PU) resin impregnated into a cotton, polyester or more usually a knitted glass fibre fabric (Wytch et al 1987a). The physical and mechanical properties of these materials have been reported (Gill and Bowker 1982; Rowley et al 1985; Rowley and Pratt 1986; Wytch et al 1987b; Martin et al 1988). We report a series of tests relevant to clinical practice with subjective opinions from patients, volunteers, and orthopaedic staff.

MATERIALS AND METHODS

A range of PU-impregnated fabric bandages were assessed and compared with POP with regard to heat production in the course of curing, moisture permeability, radiolucency, wear, and the effect of wetting on the mechanical properties of the bandage. The bandages and their composition are listed in Table I.

Heat production. The heat from POP and synthetic bandages was recorded in volunteers in below-knee

Table I. Composition of the bandages tested

Fabric	Filler
Lenoweave cotton	Plaster of Paris (POP)
Knitted polyester	Polyurethane resin (polyester/resin)
Knitted cotton	Polyurethane resin (cotton/resin)
Knitted glass fibre	Polyurethane resin (glass fibre/resin.1)
Knitted glass fibre	Low tack polyurethane resin (glass fibre/resin.2)

Fig. 1

The position of the thermistor temperature probes used to record changes in skin temperature during the curing of casts.

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Table II. Mean maximum skin temperatures under casts

	Maximum skin temperature (°C)		
	Front of ankle	Sole of foot	Heel
POP	38.6	39.4	37.7
Polyester/resin	40.2	39.1	39.2
Cotton/resin	40.5	39.9	35.0
Glass fibre/resin.1	38.4	37.2	34.9
Glass fibre/resin.2	36.8	31.9	31.4

walking casts (BKW) using thermistor probes attached to the skin at the front of the ankle, the heel and sole of the foot before application of the casts (Fig. 1). Temperatures were monitored for 25 minutes after application.

Vapour permeability. Containers holding 20 ml of water were covered with slabs of bandage, sealed with silicone rubber and placed in an incubator at 37°C and a relative humidity of 33% for 72 hours. The evaporative water loss was determined from the change in the weight of the pot after correcting for any change in weight of the material sample. The surface area of bandage covering the pot was calculated and the moisture vapour permeability (MVP) in mg/hr/m² derived.

Radiolucency. Slabs of bandage were placed over an ionisation chamber attached to a Pitman Dosemeter (Pitman Ltd, Model 37C, Weybridge, UK) and were exposed to a standard dose of radiation from diagnostic X-ray equipment. The attenuation coefficient was calculated per layer of material.

A radiographic knee phantom was wrapped with each bandage material in turn and anteroposterior radiographs taken (70 KVp, 0.15 sec) with the X-ray source 1 m from the film. Six radiologists then ranked the radiographs for radiolucency and interference with the appearance of the 'bone'.

Wear. The scuffing action on the heel of a BKW cast during gait was simulated (Wytych et al 1987b) by holding slabs of bandage in contact with a motor driven cam covered with abrasive paper for five minutes. The samples were weighed and measured before and after testing and the mass, thickness and volume loss of the material determined.

Water immersion. Cylinders of bandage were compressed at a rate of 5 mm/min and the load recorded before and after full immersion in water at 20°C for one hour. Repeat testing was carried out during the next 24 hours.

Subjective reports. Nineteen volunteers took part in a randomised trial. Each was fitted in sequence with four BKW casts, one POP and three synthetic casts. Each volunteer remained non-weight-bearing for 48 hours in POP and for 30 minutes in synthetic casts. Normal weight-bearing then followed for 48 hours in each cast and they were then inspected for evidence of wear or damage after removal. Gait assessment was performed, using a walkway fitted with a force platform. Records were made for both the cast and uncast legs, and the level of activity was recorded using pedometers.

Volunteers completed questionnaires after fitting and removal of casts concerning cast breakdown, ease of walking, heat, durability and comfort.

Patients. Questionnaires were completed by 46 patients with ankle fractures who had been fitted with either a POP or a synthetic cast, and by the three cast applicators concerning the fitting and removal of each cast.

RESULTS AND DISCUSSION

Heat. The highest temperatures were recorded at the front of the ankle in the synthetic casts and on the sole of the foot in the POP casts (Table II) within 10 minutes of the immersion of the bandages; all were significantly lower than those likely to cause thermal injury (Pope, Callahan and Lavalette 1985). The number of layers of bandage, water temperature and ventilation around the cast all have an effect on the temperature (Williamson and Scholtz 1949). Volunteers reported no significant differences in temperature sensation in different bandages.

These results confirm that neither POP nor the synthetic bandages were likely to cause burns when used in accordance with manufacturer's instructions.

Vapour permeability. The synthetic bandages generally had greater moisture vapour permeability than POP (Table III). However, four layers of POP have a relatively high permeability; this could be due to some form of 'wick' effect or to microfractures in the plaster. Synthetic

Table III. Vapour permeability of casting materials

	Moisture vapour permeability (mg/hr/m ²)	
	4 layers	8 layers
POP	85.00	62.90
Polyester/resin	99.90	86.10
Cotton/resin	114.62	112.30
Glass fibre/resin.1	84.82	79.63
Glass fibre/resin.2	90.03	68.32

Table IV. Relative radiolucency of casting materials

	Attenuation coefficient per layer	
	(mRAD)	%POP
POP	0.068	100
Polyester/resin	0.005	7.4
Cotton/resin	0.008	11.7
Glass fibre/resin.1	0.035	51.5
Glass fibre/resin.2	0.048	70.5

bandages rely on the pores formed by the mesh to allow the passage of water. These overlap with increasing layers of bandage so the permeability decreases.

Radiolucency. The crystalline structure of POP causes greater attenuation of X-rays than the PU resin-impregnated bandages (Table IV). Differences in attenuation between synthetic bandages is due to the structure of the bandage and silicate impurities in the glass fibre. In clinical use, where relatively more layers of POP are required, the differences in radiolucency are more marked.

Table V. Average loss of material on abrasion testing (see text)

	Thickness (mm)	Mass (gm)	Volume (mm ³)
POP	4.74	4.31	2411
Polyester/resin	2.04	0.80	714
Cotton/resin	2.24	0.33	797
Glass fibre/resin.1	3.78	1.25	1725
Glass fibre/resin.2	3.17	0.96	1288

Table VI. Size of cast and incidence of breakdown

	Number of rolls*	Weight (g)	Breakdown (%)	
			Volunteer	Patient
POP	8	1070	95	96
Cotton/resin	3	584	0	—
Polyester/resin	5	318	33	—
Glass fibre/resin.1	3	587	13	16
Glass fibre/resin.2	3	530	16	15

*used for an average man

Ranking of the knee phantom radiographs confirmed that POP was the least radiolucent and interfered most with visualisation of bony detail. Cotton/resin was the most radiolucent resin bandage. The large mesh of polyester resin produced a distracting pattern.

Wear. Synthetic bandages showed a greater resistance to wear than POP (Table V); the cotton and polyester bandages wore better than glass fibre. The high rate of wear of POP bandages contributed to cast breakdown.

Water immersion. The effect of water immersion is shown in Figure 2; all synthetic casts showed a decrease of up to 53% of strength, but recovered to over 90% within 24 hours. POP casts deformed permanently after loading.

Cast breakdown. As shown in Table VI, there was an unacceptable incidence of breakdown of POP casts in

both volunteers and patients. Synthetic casts had less breakdown and in the case of polyester/resin no sign of breakdown was apparent. They would have performed even better if the fabrics had been flexible but with mechanical strength similar to glass fibre.

Subjective results. Subjective opinions on various aspects of the casts are recorded in Figure 3. Volunteers wearing BKW casts had high levels of activity with pedometer readings of up to 12.7 miles in 48 hours. Both POP and synthetic casts were felt to provide rigid support to the limb (Fig. 3b). Interference with ease of walking was

Fig. 2

Effect on the strength of synthetic bandages of immersion in water and subsequent drying.

reported more often in POP than in synthetic casts (Fig. 3d), although force platform results showed only minor differences between the cast and the uncast leg.

The lighter synthetic casts provided better mobility, particularly in the elderly but there was little difference in climbing stairs or in comfort (Figs 3e and 3f).

Synthetic materials were preferred by those who applied the casts because of ease of use and absence of mess, but moulding was more difficult. Sharp edges and small particles of dust during cutting occasionally caused skin irritation. Glass-fibre fabric casts are hard and brittle; sharp edges may chafe the skin. Splinters of glass are generated during cutting with a power saw, and the airborne particles produced are small enough to reach the alveoli where long-term exposure may cause disease of the lung (Wytych et al 1988).

CONCLUSIONS

All the current range of PU-resin-impregnated bandages have better mechanical and physical properties than POP bandage. They are preferred by both patient and applicator but are significantly more expensive and potentially more hazardous than POP (Wytych et al

Fig. 3

The opinions of 19 volunteers on various aspects of wearing a BKW cast for 48 hours.

1987a). The incidence of cast breakdown in POP casts gives concern.

Despite these disadvantages POP is likely to remain the most widely used splinting material because of its cheapness and its superior moulding properties. The cost advantage of POP is, however, reduced because significantly more bandage is used for each cast and the incidence of breakdown and need for replacement is higher.

Cotton fabric bandage is less brittle and produces lighter casts but delaminates easily and is significantly weaker than glass fibre. The polyester fabric was

satisfactory in most respects, but produced bulky casts which were difficult to apply due to excessive widthwise stretch and restricted lengthwise stretch in the bandage.

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