Prosthetics and Orthotics International, 1987, 11, 42–45

Technical note

New splinting materials

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Abstract

Plaster of Paris (P.o.P.) bandage has been the pre-eminent external splinting material for over 150 years and from time to time synthetic alternatives have been tried. So far none has seriously challenged the dominance of P.o.P. as a primary or secondary material in the management of fractures. The recent introduction of Polyurethane coated fibreglass bandage appears to offer a more serious challenge than previous contenders. This technical note reviews bandage type splinting materials and explains some of the properties of the PU materials.

Background

Over the past few years, there has been an increase in the number of splinting materials available. Plaster of Paris (P.o.P.) which is still the most popular splinting material, has a long history stretching back to early times in India and Arabia. It was first used in the form of an impregnated cotton bandage by Mathijsen in 1854. P.o.P. combines ease of application and conformability with rapid setting time. It is also very cheap.

In spite of its popularity P.o.P. bandage is not the ideal splinting material. It has a poor strength-to-weight ratio, and a rapid loss of strength when brought into contact with water. Owing to its capacity to absorb and scatter X-rays, P.o.P. can adversely affect the definition of radiographs. It is messy in application and a mobile patient will have to use crutches for two days until the cast is cured before it can be fully weight bearing. Despite this, the cast may break down when subjected to full weight bearing.

To overcome the obvious disadvantages of P.o.P. bandages, numerous attempts have been made to impregnate various fabric bandages with polymeric solutions. Combination casts have been tried using an outer layer of a rapidly curing synthetic bandage, for example, *Crystona or Deltacast around P.o.P. cast. The philosophy of this approach is to combine the unrivalled moulding properties of P.o.P. with the stronger, faster curing, more water resistant, resin coated bandages. This should mean a saving on the more expensive resin coated bandages. The authors' experience with the P.o.P./Crystona combination is that it offers no advantage in terms of durability for weight bearing casts. Furthermore it does not allow earlier weight bearing than for P.o.P. alone, because body weight forces are transmitted through the single layer of Crystona to the uncured P.o.P., resulting in breakdown of the P.o.P.

Polyurethane coated bandages

(a) *Decription*

There is currently available a range of knitted fabrics (cotton, polyester, or more commonly fibreglass) coated with a moisture curing polyurethane pre-polymer which hardens after immersion in water. When correctly wrapped they produce a strong, durable cast that is weight bearing within thirty minutes.

The basic chemistry is:

$$\underset{\text{(with isocyanate end groups)}}{\text{Pre-Polymer}} + H_2O \rightarrow \begin{cases} CO_2 \\ \text{Polyurethane Polymer} \end{cases}$$

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*Trade names

The isocyanate end groups may react with any molecule containing an active hydrogen.

These polyurethane (PU) coated bandages derive a large proportion of their strength from the fibreglass substrates. Typical proportions of fibreglass to resin would be 55% fibreglass and 45% PU resin. The fibreglass substrate typically has a mesh size of forty five openings per square centimetre and a thickness of 0.75mm (Fig. 1).

(b) *Cast application and removal*

The technique of applying PU coated fabric bandages is similar to P.o.P. bandages. However the manufacturers instructions should be closely adhered to in all circumstances.

Casts can be removed using plaster shears or a plaster saw. Bivalving is usually necessary.

(c) *Mechanical properties*

In general PU coated fabrics are much stronger and tougher than plaster based materials. They are more hard wearing and have a greater fatigue strength. Their strength-to-weight ratio is higher than plaster based materials and the incidence of cast breakdown is greatly reduced. PU coated bandages regain most of their strength after immersion in water.

This will mean that casts should need replacement for clinical reasons only, for example, remanipulation or reduction of swelling, and therefore minimize the potential risk associated with frequent cast changes.

(d) *Radiolucency*

Plaster of Paris absorbs and scatters X-rays due to its crystalline structure and the thickness of the cast. This means that the fine detail of bone structure is obscured. The current range of PU coated bandages are radiolucent due to their lower density and amorphous structure. Furthermore, fewer layers are required in cast construction. This results in sharper definition of the bony structures. Some of the fibreglass weaves may provide a distracting pattern when viewing the films closely.

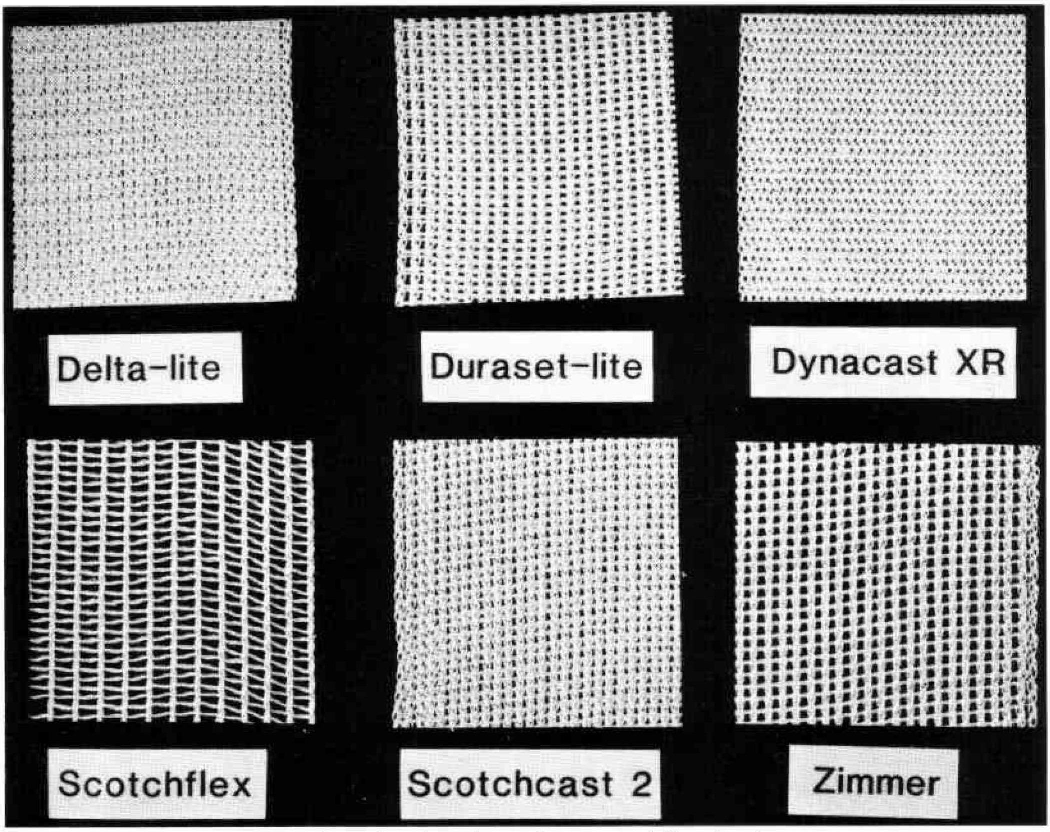

Fig. 1. Examples of polyurethane impregnated fibreglass bandages.

(e) *Potential hazards*

Some of the potential hazards associated with the current range of PU coated bandages are listed below:

(i) *Chemical*

The Polyurethane resin coated bandages described in this article are made from methylene bisphenyl di-isocyanate (MDI). This substance might present an inhalation toxicity hazard before it is exposed to moisture. Upon exposure to moisture the MDI is converted to a non-toxic, non-volatile polymeric urea substance. Free isocyanates, however, represent a small proportion of the pre-polymer element of the uncured bandage and are unlikely to be a skin or inhalation hazard to the patient or the applicator. The applicator is advised to use gloves or barrier creams to prevent the resin sticking to the hands.

(ii) *Flammability*

All polyurethane resins burn easily. When coated on a fibreglass bandage and wrapped to form a cast the ability of the bandage to burn may be modified by one or more of the following factors:

(a) Uneven distribution of resin on the fabric.
(b) Number of layers of bandage in the cast.
(c) Rucking of the bandage in the cast.
(d) "Heat sink" effect of the fibreglass substrate resulting in a reduced local temperature.
(e) The angle of the incident flame to the cast.

In practice the rate of heat transfer through the cast is such that the patient would be aware of the raised temperature before the cast had ignited.

(iii) *Toxic gas emission*

During the partial combustion of

Table 1. Comparison of currently available bandages for splinting

		Below-knee casts		
Type of bandage	Product name	No. of rolls (10cm. wide)	Average weight of cast (g)	Average cost of cast
100% Knitted fibreglass impregnated with polyurethane resin	Dynacast XR Scotchcast 2 Deltalite Dureset-lite Zimmer Scotchflex	3	580	£17.85
Knitted polyester impregnated with polyurethane resin	Dynacast	3	735	£20.10
Knitted cotton impregnated with polyurethane resin	Deltacast (Baycast)	6–8	338–434	£12.00–£16.00
Cotton mesh impregnated with a thermoplastic polyester	Hexcelite	3	515	£12.60
Aluminosilicate glass and poly-acrylic acid polymer on a cotton bandage	Crystona	6	1124	£16.74
Plaster of Paris on Leno weave cotton bandage	Gypsona	8	1183	£2.32

polyurethane resins, hydrogen cyanide, carbon monoxide and oxides of isocyanates may be produced. The quantity of the gases released from a PU coated bandage when ignited is likely to be insignificant and would only prove to be a hazard if released in an unventilated, confined space. Under these circumstances carbon monoxide is likely to present the most serious problem.

(iv) *Dust generation*

Entrapment of airborne dusts in the lungs could represent a respiratory hazard leading to fibrosis. Particles of up to 5µ may be deposited in the alveolar passages (respirable dust) while larger particles retained in the mucous membranes of the respiratory tract are eliminated by means of the lung clearance mechanism.

Airborne dust generation during cast removal with a power saw could represent a respiratory hazard if the concentration of total dust exceeds a threshold limit value (TLV) of $10mg/m^3$ or if the respirable fraction exceeds a TLV of $5mg/m^3$.

Plaster of Paris is classified as a nuisance dust by the Health and Safety Executive, however, it is anticipated that dust generation from knitted fibreglass fabric coated with PU resin would be less severe.

The majority of particles are larger than P.o.P. since they contain bandage and resin combined and are, therefore, less mobile. A particle size of less than five microns (5µ) could cause respiratory problems.

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