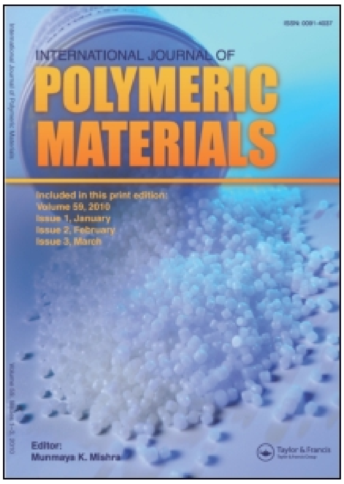

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Trans-polyisoprene Sheeting—Its use in Orthopedics and other Medical Conditions†

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The properties of synthetic trans 1, 4 polyisoprene which make it especially suitable for orthopedic appliances in medicine are described. A procedure for making a hand splint is outlined. This method can be used for most appliances with simple modification. The purposes of splinting are described. Several different types of splints are depicted giving the specific medical condition and function for which they were constructed.

INTRODUCTION

Splints can be traced to the early Egyptians. The famous Edwin Smith Surgical Papyrus, an Egyptian medical document, described 48 cases of injury. Among the treatments recommended were splints and casts for reducing dislocations and healing fractures. Two sets of splints were found on mummies in an excavated cemetery in Naga-e-der. They consisted of pieces of supporting bark wrapped in linen. The bodies were judged to be about 5000 years old.

In the 16th century, metal turnbuckle appliances were used for manipulation of the knees, and Ambrose Paré invented many corrective devices including metal corsets for scoliosis.

In more recent times, plaster of paris has been the important medium in which to immobilize fractures and to splint sprains and strains. Some disadvantages of plaster of paris are:

1) It is a fairly messy product to work with.

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†Presented at the Symposium on Elastomers in Medicine at the 105th Meeting of the Rubber Division, American Chemical Society, Toronto, Canada, May 9, 1974.

2) Many layers of plaster must be applied to obtain a strong splint, which makes it heavy and cumbersome for the patient.

3) It cannot be washed, and therefore is not completely satisfactory for hygienic and cosmetic reasons.

4) Splints constructed of plaster cannot be worn immediately, as they require up to 24 hours to dry.

5) Shrinkage occurs on drying and often the splint must be refitted. This is a distinct disadvantage in many conditions, where a splint is required immediately for a patient in an emergency situation.

Plaster of paris, however, is reasonably durable and it is porous, allowing air to get in to the skin below. This is a very important feature in orthopedic devices.

Recently, an increasing number of orthopedic appliances are being made from compositions based on trans 1, 4 polyisoprene. These compositions do not have the disadvantages of plaster of paris; nor do they have to be molded to a model or replica of the patient—as do most thermoplastics. They can be molded directly against the patient's skin.

The direct molding technique is more rapid and causes no additional discomfort, and the closer fit obtained provides more effective immobilization.

The following is a brief outline of the preparation and properties of trans 1, 4 polyisoprene, and the properties of an orthopedic composition based on this polymer, known as POLYSAR X414. Specific applications of POLYSAR X414 in the field of orthopedics and other medical conditions are described.

TRANS 1, 4 POLYISOPRENE

Trans 1, 4 polyisoprene is an isomer of the natural rubber molecule and occurs as a milky latex in a variety of tropical trees (Figure 1). Synthesis of trans 1, 4 polyisoprene became possible after the discovery of Ziegler catalyst systems for the stereospecific polymerization of dienes. A Ziegler catalyst is composed of an organometallic compound and a transition metal compound. Many combinations are known, and examples can be found in patent literature. Different systems yield trans 1, 4 polyisoprenes with different trans 1, 4 content and properties. Experiments at Polysar Limited, have shown that the crystallinity and hardness of the polymer are largely dependent on the trans 1, 4 content (Table I).

To achieve a high level of crystallinity, which is essential for good strength and rigidity, the polymer must be sterically pure; that is, it must have a very high trans 1, 4 content. A commercial process for the production of trans 1, 4 polyisoprene has been developed by Polysar Limited. Using the Ziegler-type

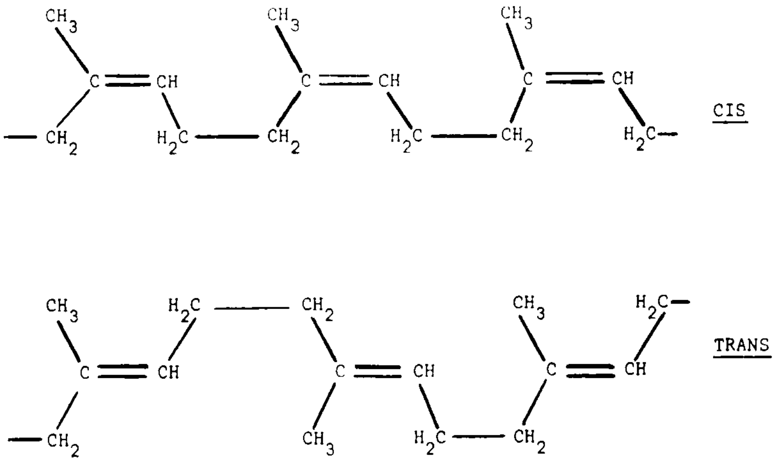

FIGURE 1 CIS- and TRANS 1, 4 polyisoprene.

TABLE I
Effect of structure on crystallinity and hardness

Polyisoprene isomeric structure % Trans 1, 4	Cis 1, 4	3, 4	Crystallinity (%)	Hardness (Shore C)
100	—	—	35	78
97	—	3	28	73
93	3	4	20	68
91	4	5	—	62

catalyst, the process produces a crystalline polyisoprene having a high trans 1, 4 content. Typical properties are shown in Table II.

Synthetic trans 1, 4 polyisoprene crystallizes at temperatures of 130°F or less. At room temperature, it exists as a crystalline rubber, and it is hard and semi-rigid at temperatures up to about 130°F. When heated to 160°-180°F, it becomes soft, plastic and self-adhering. As with other crystalline polymers, its rate of crystallization is dependent on the ambient temperature. It differs from most other polymers, however, in that crystal formation at room temperature is relatively slow. Consequently, the polymer is soft and moldable for some time at temperatures that are comfortable to the skin. This feature, together with strength and rigidity, suggested that trans 1, 4 polyisoprene could be very useful in orthopedic conditions to support or immobilize parts of the body. Like plaster, it could be applied directly to the skin, but unlike plaster it would be light, durable, unaffected by water, and cosmetically pleasing.

TABLE II

Properties of synthetic trans 1, 4 polyisoprene

Trans content (%)	98.5
Molecular weight ($\bar{M}_w$)	4×10^5
Crystallinity (%)	30
Specific gravity	0.95
Melt flow index (g/10 min) ASTM D 1525 (100°C, 10 kg load)	1.2
Vicat softening point (°F) ASTM D 1238	122
Tensile strength (psi) ASTM D 638	4700
Modulus @ 300% (psi) ASTM D 638	2500
Flexural modulus (psi) ASTM D 790	28,000
Elongation @ break (%) ASTM D 638	500
Hardness—Shore C	74

POLYSAR X414

Although trans 1, 4 polyisoprene is strong and rigid, it was felt that these properties could be enhanced by the use of reinforcing fillers. It would thus be possible to use thinner sections to provide equivalent rigidity. Experimental work along these lines resulted in the development of a composition, POLYSAR X414, containing approximately 80% polymer. This composition represented a compromise because, while mineral fillers and other reinforcing additives increase the flexural modulus and service temperature, they also reduce moldability. POLYSAR X414 has a flexural modulus at room temperature of approximately 45,000 psi, a 60% increase over the uncompounded polymer.

Laboratory tests on POLYSAR X414 showed that it provided ample molding time in applying a splint to a patient (Figure 2). A thickness of 1/8-inch was adequate to give strong support. It was noted that the material did not begin to harden for about three minutes, which is enough time for intricate molding and trimming of the splint on the patient. The material is sufficiently hard and rigid to last for a long period of time, as is often required in conditions such as rheumatoid arthritis (Figure 3). The composition is serviceable at temperatures up to about 120°F. Experiments performed by the Veteran's Administration Cosmetic Center in New York (Figure 4), assessed the strength and "creep" resistance characteristics of the material. In this test, a 4-lb tensile load was applied to a piece, measuring 3 × 1 × 3/16 inch, for10 minutes at constant temperatures ranging from 80°–130°F.

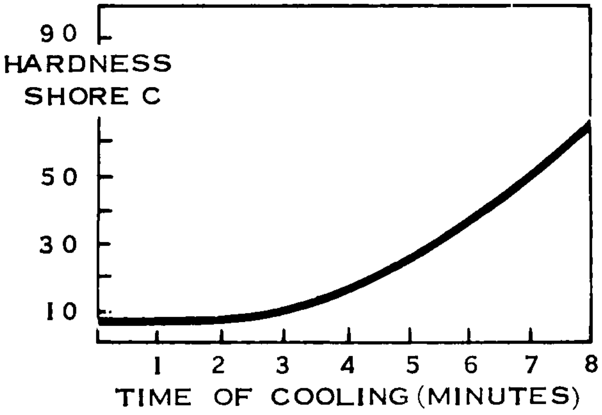

FIGURE 2 Rate of hardening.

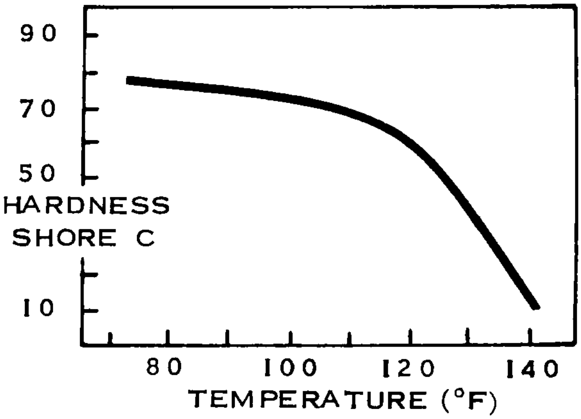

FIGURE 3 Effect of temperature on hardness.

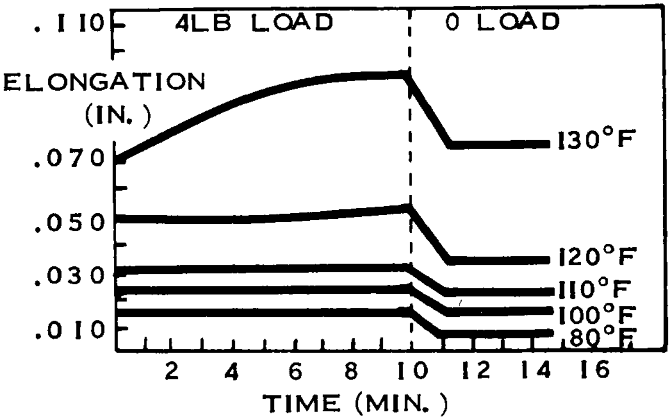

FIGURE 4 Elongation under load (creep).

The samples underwent a small initial deformation under the load, but creep thereafter was negligible at temperatures up to 120°F. The results of the test indicated that the material maintained its shape, even under stress, at temperatures up to approximately 120°F.

SPLINTS

The important features of splints are as follows:

1) The finished product should be as pleasing to the eye as possible.

2) Close contact with the affected part is necessary to provide support without pressure and friction.

3) The splint material must be non-irritating.

4) The patient should be able to apply and remove the splint after a few simple instructions.

5) A splint should be easy to mold, especially in cases of acute inflammation or trauma.

6) The material should be such that it sets quickly but allows sufficient time for shaping and trimming.

In the Rehabilitation Department of our hospital, POLYSAR X414 has become a very important medium in splint-making. It is quick and easy to use and, in experienced hands, is an excellent material in the fashioning of orthotic devices.

Figures 5-24 show the procedure that we use for making a hand splint.

1) The basic measurements of the patient's arm are taken and transferred to a sheet of POLYSAR X414. A quadrilateral shape is cut to this size.

2) This is placed in hot water just below boiling point, between 160° and 175°F. A hot air oven is an alternative method of softening the material, but in our experience hot water is more convenient.

3) The material is removed from the water and tested on one's own skin to make sure it is not too hot for the patient. It is then applied to the part to be splinted.

4) A tensor bandage secures the material to the arm, leaving the therapist's hands free to do the more intricate molding. The patient's hand is placed into a functional position, the fingers and thumb in opposition.

5) When the splint is shaped and slightly cooled but not hardened, it is removed and trimmed. Reheating is unnecessary if the material is still pliable.

A heat gun can be used to soften local areas for remolding or fusing of the material.

6) Fasteners are placed on the splint, and it is allowed to harden completely. This takes about five minutes at room temperature; one minute if immersed in cold water. Velcro fasteners are excellent and very simple for the physiotherapist to apply. The hook has a pressure-sensitive adhesive backing which adheres very well to the polymer.

This method takes 15 or 20 minutes and the patient can wear the splint immediately. The splint is cosmetic and light in weight, and the perforations in the splint material allow air to circulate. This is a major medical concern

FIGURE 5

FIGURE 6

FIGURE 7

FIGURE 8

Measure the hand and forearm.

FIGURE 9

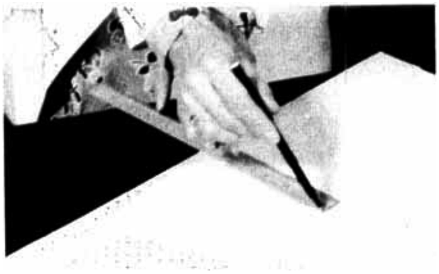

FIGURE 10

FIGURE 11

Measure and cut the sheet.

when synthetics or plastics are used, because if air is not allowed to circulate, many skin problems may result. Instructions to the patient at this point are to remove the splint two or three times per day to expose and freshen the skin. A splint can be worn for 24 hours a day and for several weeks at a time, if the skin remains in good condition.

The specific purposes of splinting are:

1) Relief of pain.
2) Reduction of inflammation.
3) Correction or prevention of deformities and contractures.
4) Improvement in function.

Basically, there are four types of splints:

1) Resting.
2) Functional.
3) Corrective.
4) Protective.

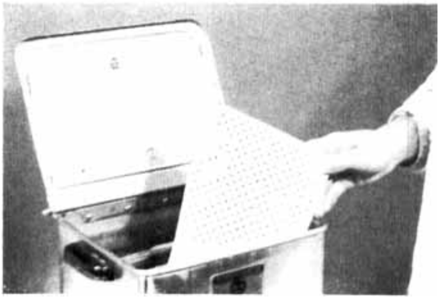

FIGURE 12

FIGURE 13

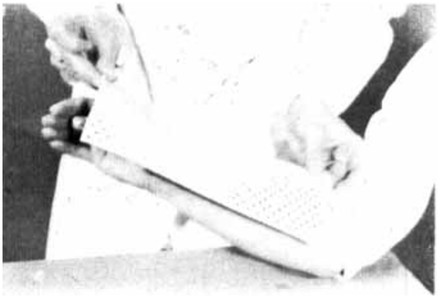

FIGURE 14

Soften and apply the sheet.

FIGURE 15

FIGURE 16

FIGURE 17

FIGURE 18

Mould and trim.

FIGURE 19

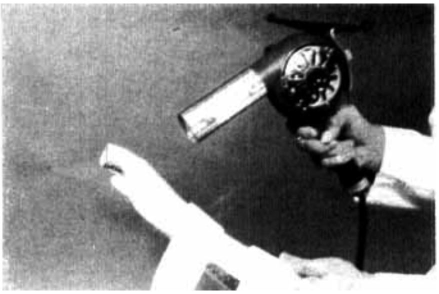

FIGURE 20

Complete shaping.

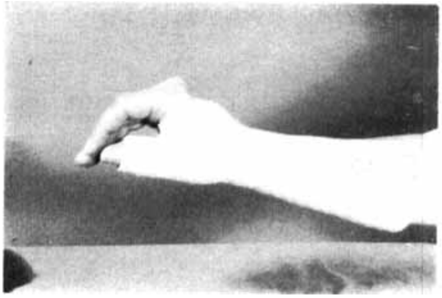

FIGURE 21

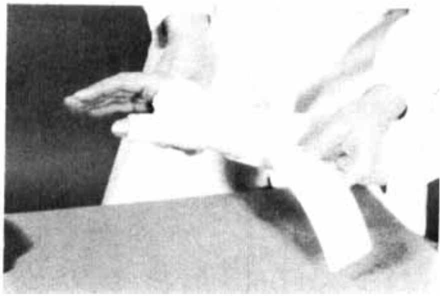

FIGURE 22

Attach fasteners.

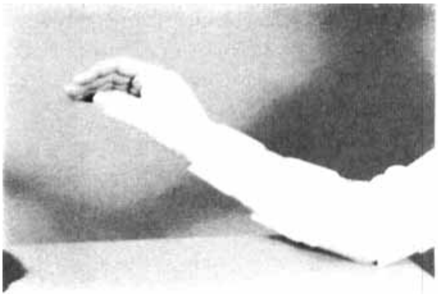

FIGURE 23

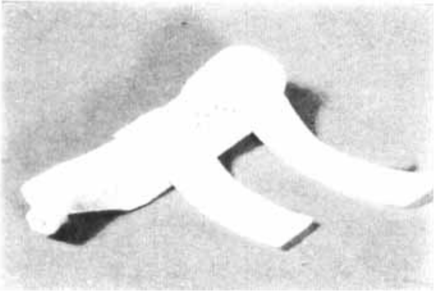

FIGURE 24

Cool the splint.

Resting splints

The ankle splint shown in Figure 25 serves as a resting splint for a fracture of the lower 1/3 of the tibia. It immobilizes the part to relieve pain, and reduces the inflammatory reaction in the structure it supports. The splint can be removed for exercise, thus preventing additional joint stiffness by allowing early gentle mobilization.

Injuries around the elbow joint can be treated with the type of splint shown in Figures 26 and 27, combining the need for early movement and intermittent immobilization.

The resting hand splint shown in Figure 28 can be used in acute inflammatory conditions; for example, arthritis involving the wrist and, primarily, the metacarpal-phalangeal joints of the fingers. It can also be used in spastic hemiplegia to prevent contractures of the fingers, thumb and wrist.

FIGURE 25

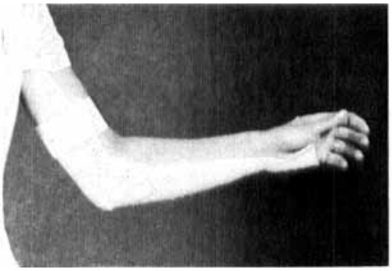

FIGURE 26

FIGURE 27

FIGURE 28

Another type is the cervical collar shown in Figures 29 and 30. It is used to support the head, relieve muscle and soft tissue pain, and restrict movement. The indications for such a collar are:

1) Acute extension-flexion injuries, commonly called "whiplash" injuries, sustained in automobile accidents.

2) Both acute and chronic cervical disc disease.

3) Post-operative conditions resulting from, for example, laminectomy or fusion of the cervical spine.

FIGURE 29

FIGURE 30

Functional splints

This type stabilizes the involved part, allowing normal movement to occur at other joints with a minimal amount of strain to the supported part.

The splint constructed is a functional splint. The patient can continue with household activities such as cooking, as shown in Figures 31–33 and with certain other activities such as clerical work (Figure 34).

Figure 35 shows another variation of the hand splint, which is made to immobilize the wrist joint and allow movement of the fingers and thumb. This splint is easily removed and replaced by the patient, and should be worn while working. Any movement that cannot be made while the splint is in place, should not be made. The physiotherapist can vary the precise position of the splint to suit the needs of a specific condition. In carpal tunnel syndrome, in which there is an irritation of the nerve, a neutral or slightly flexed position of the wrist is necessary to prevent pressure on the nerve.

FIGURE 31

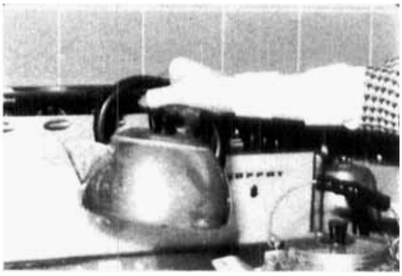

FIGURE 32

FIGURE 33

The indications for the use of this splint are:

1) Acute sprains and strains of the wrist.

2) For Colles fractures in the convalescent state; that is after a fractured wrist and early removal of plaster, a splint is applied for extra support until strength is regained.

3) In rheumatoid arthritis of the wrist and carpal joints.

4) In tenosynovitis, an acute inflammatory condition around the wrist.

This splint can also be used as a protective device in athletics (Figures 36 and 37). Each winter, such splints are made for skiers who do not wish to sit out the season because of injury. The grip is molded around the ski pole handle.

This small hand splint (Figure 38) is for very localized pain involving the metacarpal bones or joints of the thumb. Again, the hand is in a very functional position to enable the patient to grasp a pencil, pick up objects, write, type or undertake various other activities.

FIGURE 34

FIGURE 35

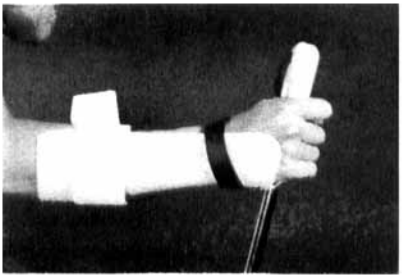

FIGURE 36

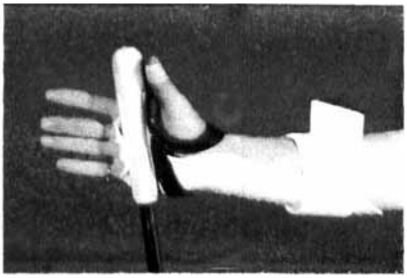

FIGURE 37

FIGURE 38

Corrective splints

As the name implies, this type of splint is used to improve the position or maintain the range of movement of one or more joints. After surgery, performed to correct deformities of the fingers in rheumatoid arthritis, the splint shown in Figures 39–41 continues the corrective process. The tensor bandage is applied tightly to increase the flexion range of stiff fingers.

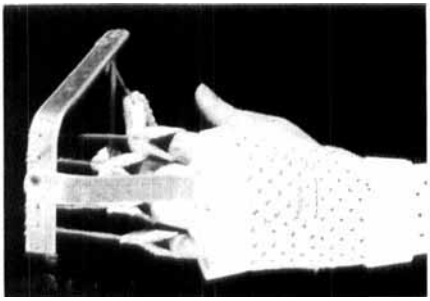

FIGURE 39

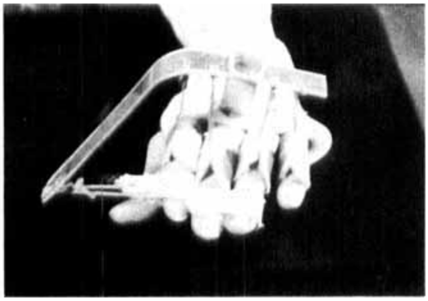

FIGURE 40

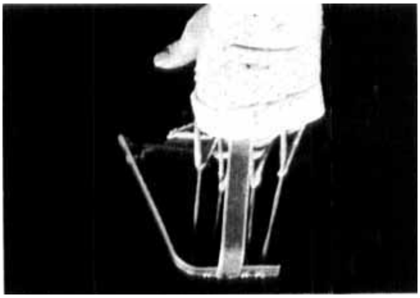

FIGURE 41

Protective splints

The 2 lb. shoulder abductor splint shown in Figure 42 replaces a 12 lb. plaster cast. This protects the shoulder, which has been surgically fused to overcome the effects of a chronic injury of three years' duration.

The main purpose of the posterior knee splint shown in Figures 43–45 is to provide support when the patient's weight is bearing on the injured leg, but it can also be used as a resting splint at night. When the patient is active, the knee is supported in a comfortably extended position by this splint.

The indications for such a splint are:

1) Sub-acute conditions of the knee joint.

2) Soft tissue injuries.

3) Chondromalacia of the patella.

4) To protect an unstable joint caused by weakened quadriceps muscles, due to trauma or resulting from an upper motor neurone disease.

5) Following surgical procedures, to allow early ambulation, i.e. after synovectomy, patellectomy or delayed union of fractures of the lower extremity.

We are not often called upon to make the type of helmet shown in Figures 46 and 47, but in certain situations it is used to prevent acute head injuries. Some patients have a tendency to fall without warning, due to dizziness or loss of balance.

POLYSAR X414 is also used a great deal in the construction of orthotic devices in children's disabilities.

FIGURE 42

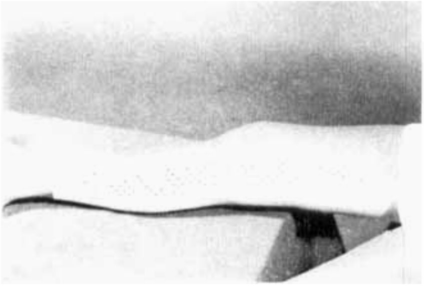

FIGURE 43

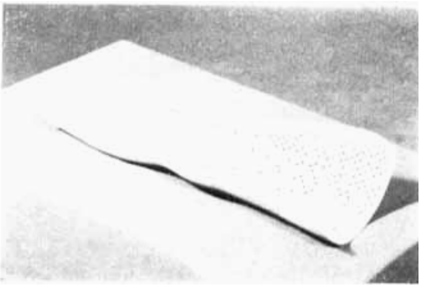

FIGURE 44

FIGURE 45

FIGURE 46

FIGURE 47

Photography by Frank Little, Medical Photography Department, The Toronto Western Hospital, Toronto, Ontario, Canada.

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