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Mechanics of knee and ankle bandages

Different types of bandages were tested mechanically and clinically. Four elastic and three elastic adhesive bandages were mechanically tested. The former proved better. Seven different ankle bandages and three knee bandages were tested in a simulated clinical situation, measuring the pressure which developed while walking for 15, 50 and 100 min, and immediately after application of the bandage. The bandages slackened most markedly during the first period of walking. The compression pressure of the padded adhesive ankle bandage was lower than that produced by most other bandages. The padded adhesive and elastic bandages proved to be most suitable for clinical use.

The padded knee bandage produced a lower compression load than the elastic bandage tested. On the basis of this trial we recommend the use of a padded knee bandage.

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The application of a bandage to support a joint is common in the management of various injuries. The compression produced by bandaging has been studied by measuring the venous flow in the lower extremity (Arnoldi 1976) and the pressure under the bandage (Glew 1967, De Bruyne & Dvorák 1976, Mills & Smillie 1979). I have measured the compression produced by different ankle and knee bandages and the change in pressure as a function of walking time.

Material and methods

The bandages tested mechanically were of two types: elastic (Futuro® Ankle Brace, Ideal EBE Binde, Dauerbinde K and Artsana ideal-tendex) and elastic adhesive (Tensoplast®, Elastoplast® and Curity®). Three parallel specimens were tested. The bandages were tested in full breadth, and the properties of the bandages were estimated by comparing bandages of different breadths per centimetre (Booth 1968).

The specimens were tested using the Alwetron TCT 20 testing machine (ANSI/ASTM D-76-67 1967), in which they were repeatedly stretched for 5 h under standardised conditions (ANSI/ASTM D-3107–75 1975). Three series were run. The pre-tension was 10 or 20 g/cm of bandage breadth, the initial elongation 0.4 mm and the traction cycle 0.4–10 or 20–0.4 per cent of specimen length. The load/elongation curves were recorded after 5, 60 and 300 min (62, 750 and 3750 traction cycles). The breaking load and length of the bandages were determined according to the Finnish Standard SFS 2983 (Suomen Standardisoimisliitto, Bulevardi 5, Helsinki, Finland).

In the simulated clinical part of the study, seven ankle and three knee bandages were tested. All bandages were applied by the same person using his customary bandaging technique. The ankle bandages were of three types: elastic adhesive (Elastoplast®, Tensoplast®), elastic (Dauerbinde K, Artsana idealtendex, Ideal EBE Binde) and padded bandages (layer, elastic adhesive) (Figure 1). They extended from the base of the toes to the calf. A gauze tube was used under the adhesive bandages. The padding was a 1–2-cm thick layer of cotton wool. In the layer bandage diagonal strips were used for support as well as the padded adhesive bandage (Viljakka & Rokkanen 1983). The outermost part of all bandages was applied as a figure-of-eight.

One of the knee bandages was of the Robert Jones type, consisting of a 3-4-cm-thick layer of cotton wool, with a 15-cm-wide elastic figure-of-eight bandage on top. The other was a layer bandage, which was also padded, but the outermost elastic bandage extended from the base of the toes to the upper margin of the bandage underneath (Figure 2). The third knee bandage was an elastic 15-cm-broad bandage (Dauerbinde K) applied in a figure-of-eight. All the knee bandages extended from the middle of the calf to the middle of the thigh (Figure 2).

The pressure under the bandage was measured

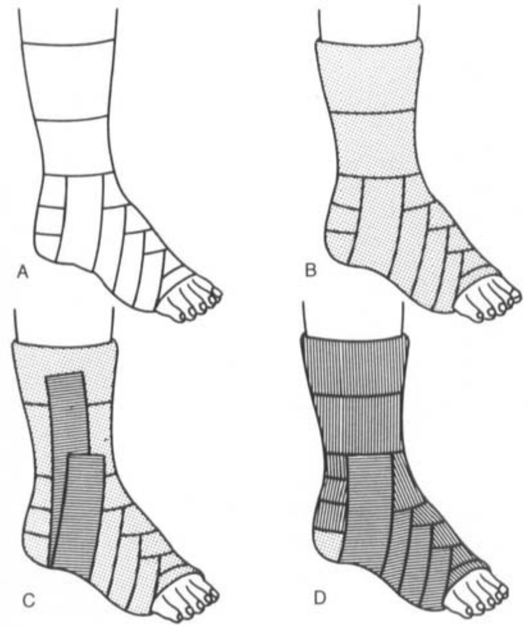

Figure 1. Padded ankle bandages. Layer bandage.
A Crepe, breadth 8 cm,
B 1–2 cm thick padding, Velband® cotton wool,
C Elastoplast® as diagonal strips, breadth 8 cm,
D Elastoplast® as figure-of-eight. The elastic adhesive bandage was the same except A gauze tube, C and D Tensoplast®, breadth 7.5 cm.

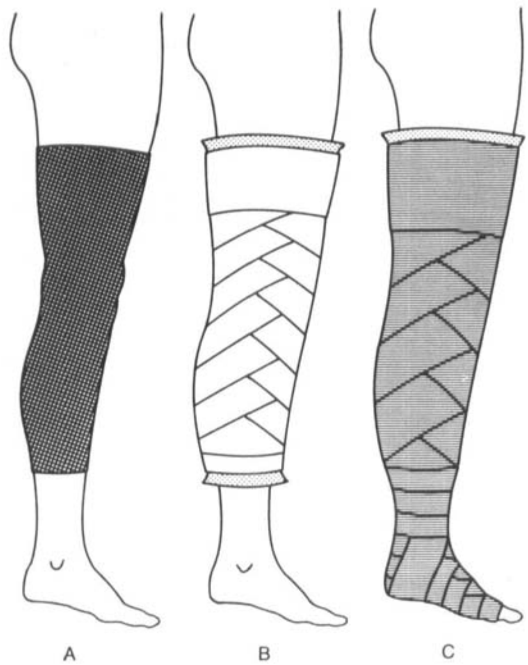

Figure 2. Layer bandage of the knee.
A Gauze Tube,
B 2-cm-thick cotton wool, a crepe bandage and a thin elastic bandage all in figure-of-eight,
C 15-cm-broad elastic bandage extending from the base of the toes to the upper margin of the bandage underneath.

immediately after application and after walking for 15 min (1.5 km), 50 min (5 km) and 100 min (10 km). All the measurements were performed by the same person using one test subject. Every bandage was tested ten times. The measurements were performed with the lower extremity of the test subject supported and the knee straight. The sites of measurement were the anterior surface of the ankle at the level of the talocrural joint and the anterior surface of the thigh above the patella. The measuring device used was a cushion-like plastic fluid chamber 2 × 12 × 16 cm in size, which was attached to the skin with tape. The chamber was filled with water (36.5°C) and joined by a piece of tubing to the recording instument (Olli Pressure Meter 295). The instrument was calibrated before use and the tube from the chamber was closed by a three-way stopcock during walking.

The results were statistically analysed by variance analysis and Scheffe's test (Guenther 1964).

Results

Elasticity. With regard to the change in elasticity after repeated stretching, it was found that the elastic bandages preserved their elasticity better than the elastic adhesive bandages ($p < 0.01$). Futuro® Ankle Brace and Dauerbinde K were best in this respect; the stretch loads changed only slightly (Table 1). The change in stretch load was smaller for these two bandages than for the remainder ($p < 0.01$). Futuro® Ankle Brace and Dauerbinde K did not differ significantly from each other, nor were any significant differences observed between the various elastic adhesive bandages.

Permanent elongation was observed when the initial load values decreased to zero on repeated stretching. Permanent elongation was recorded for the elastic adhesive bandages and to some extent also for one series of elastic bandages (Ideal EBE Binde and Artsana ideal-

Table 1. Stretch load of bandages at repeated stretching. Mean values of three test series.

	Stretch load (N/cm) Elongation length (mm) 0.4		20		Elongation of bandage after 300 min (%)	
	Stretching time (min)				Transient	Permanent
	5	300	5	300		
Futuro® Ankle Brace	0.17	0.11	1.96	1.94	0	0
Ideal EBE Binde	0.04	0	0.63	0.50	1.1	0.4
Tensoplast®	0.04	0	0.70	0.56	2.9	2.4
Dauerbinde K	0.12	0.10	0.47	0.45	0	0
Artsana ideal-tendex	0.07	0.01	0.53	0.54	0.8	0.1
Elastoplast®	0.02	0	0.74	0.59	2.6	3.1
Curity®	0.03	0	0.39	0.29	1.4	0.7

tendex). Futuro® Ankle Brace and Dauerbinde K did not show either permanent or transient elongation (Table 1). No statistically significant differences in transient elongation were noted between any individual bandages, but as a group, the elastic bandages showed smaller transient ($p < 0.05$) and permanent elongation ($p < 0.01$) than the elastic adhesive bandages.

Breaking load and length were tested on 5–6 parallel specimens. The breaking values for the elastic bandages were higher than those for the elastic adhesive bandages ($p < 0.01$). The Futuro® Ankle Brace and Dauerbinde K had the greatest breaking length, the mean being 382 and 384 mm, respectively (tension length 200 mm, traction rate 300 mm/min).

The clinical tests showed that the greatest decrease in compression load of the bandages occurred after walking for only 15 min (Table 2). Of the ankle bandages, the adhesive bandages and among the elastic bandages the Artsana ideal-tendex and Ideal EBE Binde did not dif-

Table 2. Compression load (mmHg) of seven ankle and three knee bandages after application and walking for 15 min (1.5 km),50 min (5 km) and 100 min (10 km). Mean (SD) values of ten test series.

	Compression load			
	After application	15 min	50 min	100 min
Ankle bandages				
1. Elastic adhesive				
Elastoplanst®	47 (10)	37 (7)	33 (6)	30 (6)
Tensoplast®	49 (11)	36 (7)	31 (6)	28 (6)
2. Padded bandages				
Elastic adhesive	29 (7)	24 (6)	21 (6)	19 (5)
Layer bandage	46 (10)	36 (7)	33 (6)	30 (7)
3. Elastic				
Dauerbinde K	56 (6)	47 (6)	42 (6)	30 (6)
Artsana ideal-tendex	37 (7)	27 (5)	23 (4)	22 (4)
Ideal EBE Binde	43 (7)	31 (5)	30 (5)	22 (5)
Knee bandages				
1. Padded bandages				
Robert Jones	21 (5)	16 (5)	15 (4)	15 (3)
Layer bandage	19 (4)	16 (3)	13 (2)	13 (2)
2. Elastic				
Dauerbinde K	29 (4)	26 (5)	24 (5)	23 (6)

fer from each other with regard to the initial or final phases. The Dauerbinde K and the adhesive bandages produced statistically significantly greater compression at both the beginning and the end of the test compared to the padded Tensoplast® bandage ($p < 0.05$) and the total change in compression load of the padded Tensoplast® bandage was smaller than the corresponding value for the Tensoplast® bandage ($p < 0.01$). The layer bandage did not differ from the adhesive bandages, but it produced a greater pressure than the padded Tensoplast® bandage ($p < 0.01$). The highest pressure readings were obtained with the Dauerbinde K bandage, the mean value at the beginning of the test being 56 mmHg. The compression load produced by the other elastic ankle bandages was lower at the end of the test than for the Dauerbinde K ($p < 0.01$, Table 2).

Of the knee bandages, the Robert-Jones type bandage and the layer bandage did not differ from each other to any statistically significant extent. The compression load of the Dauerbinde K was greater than that of the other two knee bandages, both at the beginning and at the end of the test ($p < 0.01$, Table 2).

Discussion

The purpose of bandaging in lower limb injuries is to prevent swelling, to support the articular ligaments in the direction of the stress to which they are exposed, without preventing normal joint movement, and to produce a steady, proximally decreasing compression of the limb. The technique of bandaging and the structure and properties of the bandage all play a part.

The bandage material should be so elastic that compression is maintained in spite of variations of swelling. Slackening of the bandage should be as slight as possible, since movement at the joints causes repeated stretching. A layer bandage may be fitted with supporting, less elastic strips intended to stabilize the joint (Viljakka & Rokkanen 1983). Elasticity is essential in circumferential limb bandages (Holzegel 1970) to prevent excessive pressure, which might cause complications (Glew 1967).

A padded bandage has certain advantages over other bandages. Compression is more even over the whole area of the bandage and also over the area of a limb with small or negative radius (Arnoldi 1976, Holzegel 1970). A thick bandage supports and immobilizes the joint (Schlein & Janes 1970, Mills & Smillie 1979), and the intermediate material prevents irritation of the skin (Distefano & Nixon 1974).

In the mechanical study, where repeated strain was imitated, the elastic bandages were significantly more elastic than the elastic adhesive bandages. The Futuro® Ankle Brace and Dauerbinde K were the most elastic of all. The applied stress produced a significant permanent elongation of the adhesive elastic bandages, while this phenomenon was not observed to any noteworthy degree in the elastic bandages.

The pressure readings obtained in the clinical test were lower than those reported in other similar investigations (Holzegel 1970, Mills & Smillie 1979). Some authors have used a mercury manometer, which is inexact, in particular with regard to low pressure readings (Holzegel 1970, Arnoldi 1976). The recommended optimal values for the compression load of bandages vary from 10 to 100 mmHg in ankle bandages (Holzegel 1970, Daintree Johnsson 1972, Arnoldi 1976) and from 40 to 60 mmHg in knee bandages (Holzegel 1970, Mills & Smillie 1979). The knee bandages tested in this study produced a clearly lower compression load.

On the basis of the results obtained in the simulated clinical study, a padded knee bandage appears safe, considering the decrease in venous pressure in the recumbent position (Daintree Johnsson 1972, Arnoldi 1976). The compression produced by all the ankle bandages tested is within the accepted range, provided that the arterial blood flow in the limbs is normal. The change in compression load was most marked at the beginning of the test series, after 15 min walking, which corresponds to the results obtained in mechanical studies (Rarick et al. 1962). The change was slighter in the knee bandages than in the ankle bandages. In addition to the purely mechanical properties of the bandage, the lowering of compression is caused, at least partly, by the shifting or compression of the bandage material and the changing volume of the limb. Replacement of the bandage during the first few days after injury should be planned, taking into consideration the swelling of the limb and the ability of the patient to walk and the bandage should be replaced as often as once a day.

The results permit the conclusion that padded elastic adhesive or elastic bandages are most suitable for bandaging of the ankle. For bandaging of the knee, a padded bandage is best. These bandages may be applied directly onto the skin. With elastic adhesive bandages a compressing effect is better obtained using an elastic intermediate material such as cotton wool.

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