ORIGINAL ARTICLE

Watch the pressure – It drops!

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Figure 1

Figure 2

INTRODUCTION

This study refers to the previous experiences reported in the Danish wound journal SÅR[1], from work presented at Jysk Sårforum discussing sub-bandage pressure measuring devices; the authors have expanded on the work with the described technique at Odense University Hospital.

A literature study primarily provided information about the initial bandage pressure and very little about the pressure over time. However, pressure drops were found to occur in other studies particularly in connection with short stretch bandages[2].

Previous experience led the authors to believe that pressure in the compression bandages tends to fall over time. The patients often reported that the bandages were quite tight immediately after they were applied, but did not feel so tight several hours later. This is particularly the case for short stretch bandages. The authors also found from experience that a compression bandage must be applied relatively firmly in order to remain in place and not loosen; in the worst cases the bandage would become loose and trail behind the patient. This situation often applies to bandages worn by outpatients when visiting the clinic for a check-up and to the bandages applied by nurses at the clinic. However, the authors had never had the opportunity to measure the pressure under the bandages, and thus had no idea of what pressure value the bandages were exerting initially and after time.

This research assumed that the desired working pressures are 40mm Hg at ankle level and 20mm Hg at calf level.[2] . A literature search primarily found information regarding the initial bandage pressure and little about the pressure over time. However, sub-bandage pressure reduction had been found before in Bispebjerg Department of Dermatology, particularly in connection with short stretch bandages.

The authors were most interested to find out how bandages, applied as normal, worked in practice over time and the question was:
At what initial pressure should a compression bandage be applied on a person with an ABI of ≥0.8 with her/his leg resting horizontally in order to maintain the recommended working pressure of 40mm Hg at ankle level and 20mm Hg at calf level for up to 10-12 hours?

A small study was conducted in which the sub-bandage pressure of two types of compression bandages and two types of elastic stockings was measured.

The authors used:

- Two Kikuhime sub-bandage pressure-measuring apparatuses with large pads. These work using a pressure system comprising a balloon, with a layer of polyurethane foam, connected via a thin tube to a measuring unit[3] (see Figure 1).

- Two compression bandages, applied following normal practices:
- A short stretch bandage with a Comprilan bandage.
  Two bandages, 10cm each, each applied according to the shape of the leg.
- A long stretch bandage with a Dauer bandage K
  One bandage, 10cm, applied spirally
- One elastic stocking, Sigvaris 222 Class II (with cotton)
- One elastic stocking, Sigvaris 503 Class II (with natural rubber)
- One elastic stocking, Sigvaris 504 Class III (with natural rubber)

The bandages were applied on the same left leg, by the same person and a new bandage was used for each application.

The elastic stockings had been acquired for the "test leg" according to measurement.

The pressure measuring apparatuses were the same and the two pads were placed in the same place on the leg for each measurement (figure 1).

Three different measurements were taken each time:

– sitting, leg in horizontal position = "application position" and resting pressure (figure 2)
– standing = load pressure
– walking = working pressure

The highest value was noted.

The results were entered in a table as shown in figure 3.

Figure 3

Time	Sitting, leg stretched = *resting pressure*		Standing = *load pressure*		Walking = *working pressure*	
Hours	Ankle mm Hg	Calf mm Hg	Ankle mm Hg	Calf mm Hg	Ankle mm Hg	Calf mm Hg
0						
1						
2 etc.						

Readings were made every hour for the first three hours, then every other hour for the rest of the day if the situation permitted.

Some of the bandages were not removed at night.

The measurements were repeated for three days for each bandage and stocking type.

The pressure reduction was then stated as a percentage reduction compared with the initial pressure, which is 100%; i.e. if the initial pressure (the pressure upon application) was 100mm Hg and the pressure dropped to 85mm Hg, the pressure was recorded as having decreased to 85% of the initial value. It could also be stated that the pressure fell by 15%.

The short stretch bandages lost resting pressure at the ankle, down to 60 → 55% of the initial pressure during the first three hours. During the 11 hours until the bandage was removed, the resting pressure at ankle level reduced to approximately 50% of the initial resting pressure.

The working pressure, measured at ankle level, reduced during walking to 75 → 60% of the initial pressure within the first three hours. After a wearing time of 11 hours, the working pressure reduced to approximately 55% at ankle level.

A short stretch bandage applied with an initial resting pressure of 52mm Hg at ankle level and 27mm Hg at calf level shows an initial working pressure of 69mm Hg at ankle level and 29mm Hg at calf level. After three hours the working pressure fell to 41mm Hg at ankle level and 12mm Hg at calf level (see Table 1).

Subsequent pressure reductions are very modest. In one case the bandage was not removed at night (i.e. it stayed on for 22 hours) and there were no further significant pressure changes. In the daytime, variations with brief increases of pressure and subsequent reductions were seen. We attributed such increases and falls to activity and therefore increased muscular tone.

In addition, in this case there was oedema when the bandage was applied and it must be assumed that the pressure would fall further if oedema was initially present and then reduced.

Table 1

Short stretch bandage						
Time	Sitting, leg stretched = *resting pressure*		Standing = *load pressure*		Walking = *working pressure*	
Hours	Ankle mm Hg	Calf mm Hg	Ankle mm Hg	Calf mm Hg	Ankle mm Hg	Calf mm Hg
0 application	**52**	27	66	28	69	29
1	42 (80%)	18 (67%)	49	20	51 (74%)	18 (62%)
2	34	15	47	17	47	17
3	29 (56%)	13 (48%)	44	16	41 (59%)	12 (41%)
7	27	11	34	11	**38**	10
11	26 (50%)	10 (37%)	34	11	37 (54%)	10 (35%)

The parentheses state the percentage of the initial pressure upon application.

The long stretch bandages generally lost resting pressure at ankle level, down to approximately 90 → 85% of the initial pressure during the first three hours. During the 11 hours until the bandage was removed, the resting pressure at ankle level reduced to approximately 70%.

The working pressure measured at ankle level reduced to approximately 90% of the initial pressure within the first three hours. After 11 hours' wearing time, the working pressure reduced to approximately 85% at ankle level. The larger the initial pressure at which the bandage was applied, the greater the percentage of pressure lost.

A long stretch bandage applied with an initial resting pressure of 42mm Hg at ankle level and 23mm Hg at calf level showed an initial working pressure of 47mm Hg at ankle level and 24mm Hg at calf level. After three hours the working pressure fell to 42mm Hg at ankle level and 21mm Hg at calf level (see Table 2).

Again, there was no oedema to affect pressure levels. However, the bandage did not appear to lose any appreciable resting pressure after approximately five hours and in the one case where the bandage was not removed at night (i.e. stayed on for 24 hours), the pressure was more or less maintained.

Table 2

Long stretch bandage

Time	Sitting, leg stretched = *resting pressure*		Standing = *load pressure*		Walking = *working pressure*	
Hours	Ankle mm Hg	Calf mm Hg	Ankle mm Hg	Calf mm Hg	Ankle mm Hg	Calf mm Hg
0 application	**42**	23	45	25	47	24
1	35 (83%)	22 (96%)	42	25	45 (95%)	23 (96%)
2	37	21	42	23	45	22
3	36 (86%)	21 (91%)	40	23	42 (89%)	21 (88%)
7	33	20	41	22	**40**	21
11	30 (71%)	20 (87%)	39	21	40 (85%)	21 (88%)

The elastic stocking with natural rubber both Class II and III were very stable in terms of pressure.

Elastic stocking, Sigvaris 503 Class II: The resting pressure reduced to approximately 80% of the initial pressure at the ankle level and approximately 88% at the calf level during the first five hours. Further loss of pressure, measured after 11 hours wearing time was moderate.

Working pressure is very stable. After five hours, pressure reduced to approximately 90% at the ankle level, and to approximately 95% at the calf level of the initial pressure. (See table 3)

Elastic stocking, Sigvaris 504 Class III: The resting pressure reduced to 85% of the initial pressure at ankle level and 90% at calf level over the first five hours. Subsequent pressure drops after 11 hours were rather modest.

The working pressure was very stable. At ankle level there was a drop to approximately 95% of the initial pressure after five hours, while the pressure at calf level was maintained (see Table 3).

Table 3

The elastic stocking, Sigvaris 503 Class ii

Time	Sitting, leg stretched = *resting pressure*		Standing = *load pressure*		Walking = *working pressure*	
Hours	Ankle mm Hg	Calf mm Hg	Ankle mm Hg	Calf mm Hg	Ankle mm Hg	Calf mm Hg
0 putting on	**32**	17	28	17	32	17
1	29 (91%)	17 (100%)	28	17	29 (91%)	16 (94%)
2	26	17	28	16	29	16
3	26 (81%)	15 (88%)	26	16	29 (91%)	16 (94%)
7	26	15	26	15	**29**	16
11	24 (75%)	13 (76%)	25	14	28 (88%)	16 (94%)

Table 4

The elastic stocking, Sigvaris 504 Class III

Time	Sitting, leg stretched = *resting pressure*		Standing = *load pressure*		Walking = *working pressure*	
Hours	Ankle mm Hg	Calf mm Hg	Ankle mm Hg	Calf mm Hg	Ankle mm Hg	Calf mm Hg
0 putting on	**38**	28	37	29	41	27
1	34 (90%)	29 (104%)	36	27	39 (95%)	28 (104%)
2	33	25	37	28	40	28
3	32 (84%)	25 (89%)	36	28	38 (93%)	27 (100%)
7	32	24	35	28	**37**	27
11	32 (84%)	24 (86%)	35	27	37 (90%)	27 (100%)

The elastic stocking with cotton lost a little more pressure over time than the stocking with natural rubber. After six hours the resting pressure reduced to approximately 90% of the initial pressure at ankle level. After a wearing time of 11 hours, the pressure fell to approximately 80%.

The working pressure reduced to approximately 95% of the initial pressure at ankle level over six hours, and after 11 hours' wearing time it fell to approximately 85% (see Table 5).

Table 5

The elastic stocking, Sigvaris 222 Class ii						
Time	Sitting, leg stretched = *resting pressure*		Standing = *load pressure*		Walking = *working pressure*	
Hours	Ankle mm Hg	Calf mm Hg	Ankle mm Hg	Calf mm Hg	Ankle mm Hg	Calf mm Hg
0 putting on	**27**	16	29	17	30	17
1	26 (96%)	16 (100%)	29	17	30 (100%)	17 (100%)
2	25	15	28	17	29	17
3	24 (89%)	13 (81%)	28	16	**28** (93%)	16 (94%)
7	23	13	28	15	27	16
11	22 (82%)	12 (75%)	27	15	26 (87%)	16 (94%)

DISCUSSION

Short stretch bandages

In general, it is difficult to say how the short stretch bandages "behave" because that depends on how the bandage is applied and how many layers are used, and the fact that the bandage is applied according to the shape of the leg and not according to a particular model.

What was interesting was to identify the perfect initial resting pressure at ankle level when applying the bandage that would ensure an optimum working pressure at ankle level during the greatest part of the wearing time.

The measurements showed that the working pressure at ankle level after 7-8 hours dropped to approximately 75% of the initial resting pressure. If it is desirable for the bandage to exert a working pressure of approximately 40mm Hg at ankle level and approximately 20mm Hg at calf level most of the wearing time, then it means that the bandage should be applied with a resting pressure of 50-50mm Hg at ankle level and approximately 30-35mm Hg at calf level (see Table 1).

This means that a short stretch bandage should be applied with an initial resting pressure at ankle level corresponding to 40mm Hg + approximately 25%. The bandage will attain (drop to) the right pressure after approximately three hours and will subsequently, according to the measurements taken, remain fairly stable in terms of pressure on a non-oedematous leg.

The pressure must be assumed to drop somewhat further if any oedema is reduced and therefore it will be necessary to apply the bandages with a higher initial pressure and/or more frequent reapplications than is presently the practice. Currently the bandages typically stay on for two to three days depending on any need for changing wound dressings.

The consequence of applying the bandage with a higher pressure is unknown and needs to be carefully evaluated. One should, in any case, make sure that the patient has an adequately high arterial pressure verified by means of a Doppler ultrasound.

According to LaPlaces Law[4], the factors to be considered when applying a bandage are:

$$P = \frac{T \times N}{C \times W}$$

P = sub-bandage pressure in mm Hg
T = bandage tension in Kg
N = number of bandage layers
C = leg circumference in cm
W = bandage width in cm

The tension of the bandage may be the same upon application, as the above factors will ensure a graduation of the pressure up the leg.

Our small study has enabled the authors to pinpoint the following important elements in connection with compression treatment using a short stretch bandage:

- Frequent reapplication of the bandage must be recommended; minimum once a day as long as oedema is present.
- In order for the bandage to remain effective during the entire wearing time, the bandage must be applied in a way that allows for the pressure reduction that was found to take place.

Long stretch bandages

Again, the authors wanted to identify the perfect initial resting pressure at ankle level when the bandage was applied that would ensure the recommended working pressure of approximately 40mm Hg at ankle level during the entire wearing time.

The measurements showed that the long stretch bandage is very stable in terms of pressure. The working pressure at ankle level after 7-8 hours only dropped to approximately 95% of the initial resting pressure.

Provided that it is desired for the bandage to exert a working pressure of approximately 40mm Hg at ankle level and approximately 20mm Hg at calf level, the band- ▶

age should consequently be applied with a resting pressure of 42-45mm Hg at ankle level and approximately 22mm Hg at calf level (see Table 2). This means that a long stretch bandage should be applied with an initial resting pressure at ankle level corresponding to 40mm Hg + approximately 5-10%. The working pressure will stabilise at the desired pressure level after approximately three hours. Subsequently the bandage was found to be stable in terms of pressure over a period of 12 hours – and after 22 hours.

Again, oedema should be taken into consideration in the same way as described under short stretch bandages.

According to LaPlace's Law, the tension of the bandage upon application must again be the same, as the increasing circumference of the leg will automatically graduate the pressure of the bandage up the leg, if the application method used by the authors is followed (spiral with approximately 50% overlap all the way up the leg).

Elastic stockings

– *with natural rubber*: The pressure also reduces under both the class II and class III stockings with natural rubber. After five hours, the working pressure is approximately 85% of the initial value. The elastic stockings proved to be exceptionally stable in terms of pressure and after 11 hours' wearing time, a working pressure of 90%/ 91% of the initial value is still maintained.

These types of stockings must be said to be pressure efficient provided that it is adjusted to a non-oedematous leg.

– *with cotton:* From the start, this stocking exerts a smaller pressure than the stockings with natural rubber (Sigvaris 503) even though the classification of the two stockings is the same. However, its reduction in pressure over time is not significantly larger than for the stockings with natural rubber.

Over 11 hours' wearing time, the working pressure reduces to approximately 85% at ankle level.

WHICH TYPE OF BANDAGE DO WE RECOMMEND TO WHOM AND WHY?

Do clinicians choose bandage type based on the change frequency and economy? Is this the basis on which to make a decision?

Measurements have indicated that the long stretch bandages, on the basis of their ability to maintain a uniform pressure over time, are the most effective.,. However, in practice, using them in co-operation with the home care service may be rather difficult considering the alternatives available. Long stretch bandages should preferably be applied in the morning before the patient rises. Often the patient will then remove the bandage him/herself at bedtime but sometimes the bandage is removed several hours before the patient goes to bed because the carer (often the home care service) is visiting the patient at that time.

In practice, therefore, short stretch bandages are often used, usually based on the argument that they can stay on for several days, depending on whether there is any need to change the dressing of a wound. When compared with long stretch bandages and the limitations of availability of assistance, this provides a good argument in favour of the use of short stretch bandages if the patient has no oedema and the bandage is applied in such a way that it allows for a pressure reduction.

Using elastic stockings often requires assistance from the home care service, due to the difficulties of application and removal, they are rather tight and many users are too weak or have physical disabilities that make it difficult for them to handle this task themselves. For some this situation may be alleviated by using an Easy Slide; a special aid for putting on elastic stockings.

Elastic stockings are classified, but there are no standardised requirements for pressure in mm Hg within the various classes, also, the stockings are made from different materials but the classification does not take the properties of the different materials into consideration. Elastic stockings are more generally used when the ulcer is healed, or nearly healed, and there is little or no oedema in the leg.

In order to optimise the compression treatment, it is expedient to try to involve and instruct the patients so that they share the responsibility for their own treatment. In the same way, the staff should be given further training in the understanding and handling of the tasks.

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