# Inelastic compression by bandages: effective, but requiring education

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Based on experimental work, a practical definition of inelastic material is provided and some superior effects concerning an improvement of the venous haemodynamics are emphasised in this article. In contrast to elastic compression, this material can narrow the veins in the upright position and to exert beneficial haemodynamic effects by abolishing reflux and improving the venous pump. The main disadvantages are the fact that proper application is not easy and that these inelastic bandages lose pressure quickly. Most inelastic bandages are applied with a pressure that is too low. Training courses in which the sub-bandage pressure can be checked by adequate measuring instruments may improve this situation. Self-applied Velcro® devices where the pressure can be measured by the patient using simple measuring aids provided by some companies may be a valuable alternative. The patient feels which pressure is beneficial and can readjust the system whenever it is getting loose. Newly developed pumps are also of increasing interest.

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The terminology of different bandage types is confusing. Depending on the extensibility, inelastic bandages may either be no- stretch or short stretch. Zinc paste-impregnated non-stretchable textiles with an extensibility of 0-5% are an example for no-stretch material, while short stretch is defined by a maximal extensibility of 100% — examples include: Ideal-Binde® (Lohmann & Rauscher), Rosidal K® (Lohmann & Rauscher) and Comprilan® (BSN Medical). Elastic (long-stretch) bandages can stretch more than 100% of their original length — examples include: Ace-bandage™ (3M), Surepress® (ConvaTec), Tensopress® (BSN Medical) (Partsch et al, 2008).

Commonly used bandage systems, for which the term 'multicomponent bandages' seems to be more appropriate than 'multilayer-bandages', contain a combination of different materials (e.g. a padding layer or adhesive outer layer). An example is the four-layer bandage, which consists of four different partly elastic components and which functions as an inelastic system. The elastic property of such bandages cannot be predicted by laboratory tests, but sub-bandage pressure measurements on the leg are required to assess the effects of these systems (Partsch et al, 2008).

Modern multicomponent systems, which are less bulky, use only two components, e.g. Coban™ 2 Layer Compression System, Rosidal TCS® (Lohmann & Rauscher), and are easier to apply (Partsch et al, 2014; Harding et al, 2015)

The effects of a compression device on the leg are more relevant than the textile properties of the single components. Therefore, statements like "multi-component systems containing an elastic bandage appear to be more effective than those composed mainly of inelastic constituents" (O'Meara et al, 2012) are misleading. It is not the presence of an elastic component that causes better effects; the enhanced performance is due to better application on the leg promoted by elastic material, which is easier to handle. In the future, pressure measurements on the leg will be necessary to achieve reliable comparisons between different compression systems, usually performed in the upright position.

## Why inelastic compression?

To compress a leg vein in the upright position, a pressure between 60 and 90 mmHg is required (Partsch and Partsch, 2005). To achieve this pressure range by elastic material, very high values would

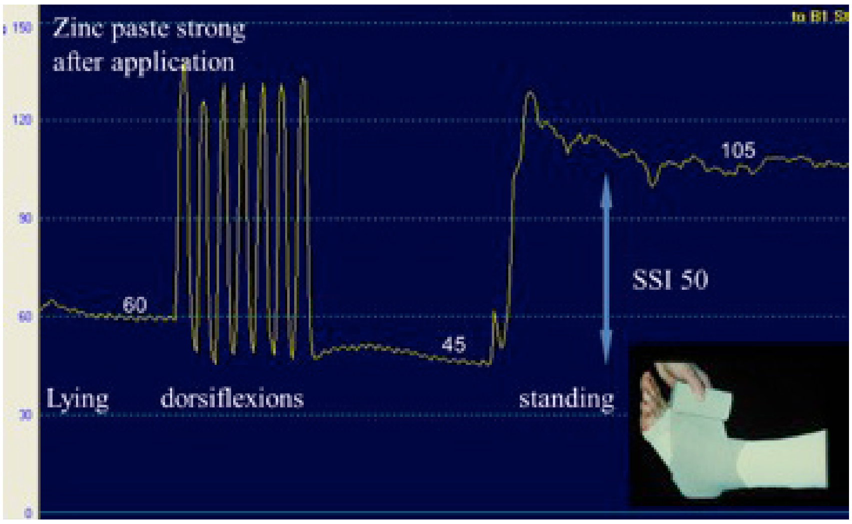


*Figure 1. Sub-bandage measured under strongly applied zinc paste bandage wrapped over by an inelastic bandage (Rosidal K) (Fischer-bandage). There is a pressure fall to 45 mmHg already after 7 dorsiflexions. By standing up the pressure rises to 105 mmHg the static stiffness index (SSI) is 105-45= 50 mmHg.*

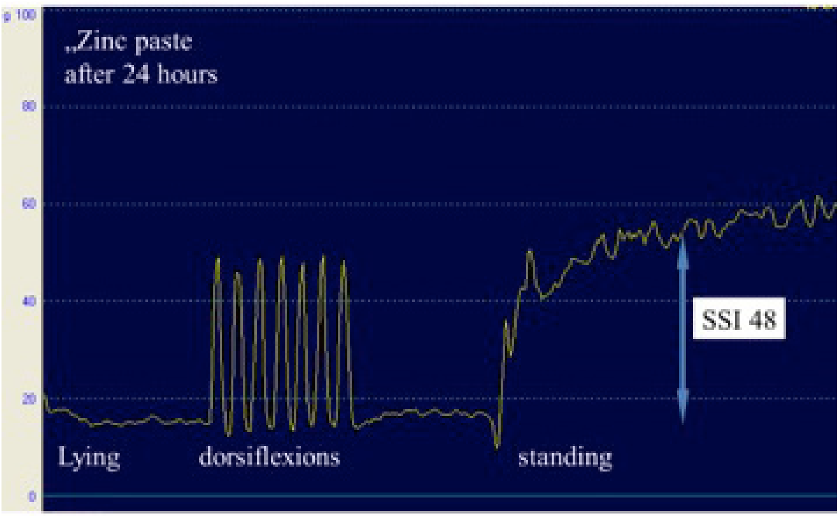


*Figure 2. After 24 hours, the resting pressure dropped to less than 20 mmHg, however the pressure increases to 60 mmHg by standing up. The SSI is only minimally lower than it was after application 24 hours ago.*

also be needed in the resting position, which would not be tolerated. In contrast, inelastic material provides very strong compression (>60 mmHg) in the upright position with much lower resting pressures. In addition, inelastic material will lose pressure immediately after application so that the pressure will fall into a well-tolerated range very quickly.

As can be seen in *Figure 1*, the very high resting pressure under a completely inelastic zinc paste bandage shows arterial pulsations, which can also be felt by the patient. These pulsations create a massaging effect even in completely immobile patients and reduce capillary filtration. Due to a fast decongestion of the leg, the compression pressure falls immediately into a range that is well tolerated. As shown in *Figure 2*, the resting pressure of the firmly applied zinc paste bandage is reduced to values lower than 20 mmHg after 24 hours and the arterial pulsations in the pressure tracing have disappeared. However, there is still a high pressure increase when the patient stands up or starts to walk. This high pressure is the reason why inelastic bandages are haemodynamically still effective after several days, despite the loss in resting pressure (Mosti and Partsch, 2010).

The rule that inelastic bandages have a low resting pressure is correct only several hours after application, and should not induce bandagers to apply such bandages with a too low pressure.

Inelastic compression causes an increase of the pressure due to the enlargement of the leg circumference, an increase of the tissue consistency and to changes of the leg configuration, depending on the measuring site (Partsch et al, 2016).

Under the European regulations for compression stockings (Comité Européen de Normalisation, 2001), 'stiffness' is defined by the increase of pressure due to an increase of the leg circumference. This term has been adopted for *in vivo* studies. The so-called 'static stiffness index' is defined by the pressure difference between the standing and lying position, while the 'dynamic stiffness index' is defined by the difference between the pressure peaks and the resting pressure. It is evident that the magnitude of these indices depends on the localisation where pressures are measured and on the type and dimension of the measuring probe. Examples for the calculation of the static stffness index can be seen in *Figure 2*. These *in vivo* results not only depend on the increase of the leg circumference, but also on the changes of the configuration and the consistency of the tissue.

Although these *in vivo* parameters are, therefore, quite variable, it turned out that measuring the pressure over the so-called B1 point (the location where the muscular part of the medial gastrocnemius muscle turns into the tendinous part), as a rule of thumb, SSI-values >10 correspond to a stiff, inelastic compression, while values <10 are typical for elastic, yielding textiles. Individual comparisons allow more reliable assessment of the elastic property of a compression system (Mosti et al, 2008a).

High pressure peaks during walking lead to an intermittent occlusion of leg veins during walking, thereby blocking venous reflux and improving the venous pumping function. Several studies have shown that stiff compression exerting a resting pressure of >50 mmHg reduces venous reflux (Partsch et al, 1999) and ambulatory venous hypertension (Partsch, 1984), and enhances the ejection fraction of the calf pump much more than elastic material (Mosti et al, 2008b).

Inelastic material is also the basis for a 'modified compression' in patients with concomitant arterial occlusive disease in whom the sustained pressure should not exceed the arterial perfusion pressure. It could be shown that in patients with an ankle–brachial pressure index (ABPI) between 0.5 and 0.8 an inelastic bandage applied with an initial resting pressure not exceeding 40 mmHg is able to improve venous pumping function and even increases the arterial inflow (Mosti et al, 2012a).

## How to handle inelastic bandages

The bandager should keep in mind that the resulting pressure depends only on the amount of stretch during application and not provided by the elastic behaviour of the bandage. Bandagers being used to apply elastic bandages usually apply inelastic bandages not strong enough (Protz et al, 2014; Zarchi and Jemec, 2014). To achieve a target pressure of 50–60 mmHg, the bandage roll should be applied with 'full stretch', exerting a pressure with the bandage roll to the skin and tightening it firmly after each tour. When two bandages are applied over each other it must be considered that the second bandage will add pressure to the first. The material should be adjusted to the leg in such a way that the pressure is equally distributed and that dips and pumps should be avoided. It depends on the shape of the leg if this is rather achieved by circular tours or by a figure of eight pattern. The technique of proper use of inelastic bandages cannot be learned through reading textbooks and needs to be trained in hands-on courses. Measurements of the achieved pressure, can be very helpful for training purposes (Hafner et al, 2000; Keller et al, 2009; Protz et al, 2014; Zarchi and Jemec, 2014).

In contrast to elastic textiles, inelastic bandages can stay on the leg for up to 1 week or even longer, and most core components can be washed and reused.

## Prerequisites for effective compression

Although interrelated, two main effects of compression should be differentiated: the action on oedema, and on haemodynamics. Low pressures are already effective to prevent or reduce oedema (Mosti et al, 2012b). Compression not only reduces fluid filtration, but also prevents leucocyte adhesion to the endothelial cells as a first step of inflammation. If a mechanical effect on the veins should be achieved, much higher pressures are required, especially in the upright position. As shown by ultrasound and MRI, compression stockings in a pressure range up to 30 mmHg in general have only minor or no effect concerning a reduction of vein diameters (Partsch and Partsch, 2005; Partsch et al, 2010).

The main features of compression that should improve the venous haemodynamics are a tolerable pressure at rest and a high pressure in the upright position to counteract gravity.

## Practical limitations of inelastic compression

The most important limitation of inelastic compression is failure of the bandager to effectively apply bandages, demonstrated in various studies. In a study measuring the pressure of different kinds of compression bandages applied by 68 home care nurses in Denmark, more than half the nurses applying inelastic (38 [56%]) and elastic (36 [53%]) bandages obtained pressures less than 30 mmHg (Zarchi and Jemec, 2014). In another study from Germany, sub-bandage pressures were measured at education seminars and workshops between 2011 and 2013. Only 10% of 551 nurses achieved a sub-bandage pressure in the postulated target range of 50-60 mmHg (Protz et al, 2014). Short-stretch bandages (Rosidal® K (Lohmann & Rauscher) and Pütter bandages (Hartmann)) were used. Three out of four bandages were too loosely applied, with a pressure around 30 mmHg (Protz et al, 2014).

These studies emphasise the difficulty of achieving the desired sub-bandage pressure and show that a substantial proportion of patients with venous leg ulcers do not receive adequate compression therapy. Training programmes that focus on practical bandaging skills should, therefore, be implemented to improve the management of venous leg ulcers.

It could be demonstrated that training was able to improve this situation (Hafner et al, 2000; Keller et al, 2009). Even nurses with everyday experience in compression therapy can improve their accuracy (Hafner et al, 2000). In another study, it was demonstrated that nurses with more than 10 years of working experience failed to apply bandages appropriately and that continuous awareness and training are necessary to maintain an adequate compression bandaging technique (Keller et al, 2009). However, long-term studies will be needed to prove that proper training using sub-bandage pressure measurements will improve clinical outcomes.

Another disadvantage of inelastic bandage is the fast pressure loss, depending on the amount of initial oedema, the initially applied pressure, the patient's activities and the composition of the bandage (Mosti and Partsch, 2010). This may lead to slippage of the bandage and skin wrinkles leading to friction and to skin lesions. The pressure loss is mostly due to oedema reduction and only to a minor extent a sign for fatigue of the compression material.

## Potential solutions

### Education and training

Better knowledge and training of compression therapy is needed. Compression is still an underestimated treatment modality, not only in the field of phlebology and lymphology, but also in traumatology, orthopedics and general surgery. Special compression courses preceded by theoretical instructions should be offered in nursing schools, for the education of paramedics, but also in the curriculum of medical students. Proper compression cannot be learned by textbooks, but requires practical advice. Pressure measuring probes that measure the sub-bandage pressure are helpful training instruments.

### Self-management using Velcro devices and pumps

Another approach is to promote education towards self-management in patients with severe venous or lymphatic disease who need strong compression. Velcro devices that can be self applied and readjusted offer a rational way out from this dilemma. Those patients experienced with the beneficial effects of good compression are learning fast to apply Velcro products tightly and to readjust them according to their subjective feeling (Damstra and Partsch, 2013). Simple pressure-measuring aids provided by some companies may be considered as a safety feature and can be helpful, especially to guide patients in the initial treatment phase, or in patients with concomitant arterial occlusions, who may be candidates for 'modified compression' not exceeding 40 mmHg. Until now, the research evidence for the use of adjustable compression wrap devices is rather limited.

Other options to achieve sustained pressure are devices that provide constant pressure by using air-filled sleeves with pumps (Mayrovitz et al, 2015; Harding et al, 2016). Intelligent systems, which can adjust the pressure automatically to the body position, are also currently under development. Despite the higher costs of these devices, self-management is more economical due to the reduction of associated nursing costs (NICE, 2015).

## Conclusions

When high pressure is needed for patients with severe venous disease or lymphoedema, inelastic compression providing high-working pressure, but a tolerable resting pressure is superior. However, its application needs to be learned and trained. Velcro devices or new pumps, which can be handled by the patients themselves may be a valuable alternative. The leg, but not the bandage, should give way. WINT

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