Pressure Applied By Elastic Prosthetic Bandages: A Comparative Study

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INTRODUCTION

Edema of the residual limb following amputation is a universal problem. The accumulation of this edema is due to several factors; handling of the tissues during surgery, post-operative inactivity and lack of muscle tone in the residual limb. As prosthetic fitting is not possible without reduction and control of edema in the immediate post-operative phase following amputation, edema must be kept to a minimum. Edema can be an additional problem for a patient who has a prosthesis but who does not use the prosthesis for several days because of some medical or prosthetic problem.

Current methods used for reduction of edema include elastic bandaging, elastic shrinkers, pneumatic shrinkers and rigid dressings in the immediate post-operative phase. Of these, elastic bandaging is the most commonly used method.

On reviewing the literature very little has been written about the ideal external pressure which should be applied to reduce edema. A number of studies[1,3,4,5,6,18] have examined the effects of external pressure on venous and skin flow and also edema reduction in the whole limb. J. B. Redford[16] compared the effects of pneumatic and "Tubigrip" (elastic) shrinkers and concluded that both devices result in satisfactory reduction of edema although pressures were not measured under the residual limb in his study. Isherwood, et. al.[8] compared the pressure exerted by an elastic wrap, a pneumatic bandage and "Puddifoot dressing" in amputees. The "Puddifoot dressing" is an elastic stocking applied over a polyurethane foam lining.[15] These investigators found that there was great variation in range of pressure applied by elastic wrap and the pneumatic bandage. Pressures ranging between 15 to 25 millimeters of mercury were reported. The "Puddifoot" stocking applied a lower pressure of 10 to 12 millimeters of mercury.

Prior to this project, we reviewed several studies on the effect of external pressure in both reduction of edema and venous return.[1,3,4,5,6,18] From this review we concluded that an ideal pressure range should be around 20 to 25 millimeters of mercury and a range of 15 to 30 probably acceptable. With the help of one of the manufacturers of elastic shrinkers we developed an elastic stocking which would maintain this "ideal pressure" for a prolonged period of time. We compared the pressure applied by the elastic bandage and another elastic shrinker currently available.

MATERIALS AND METHOD

Lower limb amputees were selected from among the patient population from the Kansas University Medical Center, Kansas City, Kansas and the Veterans Administration Medical Center in Kansas City, Missouri. A total of 41 amputees were studied ranging in ages from 15 to 55 years. The length of time post amputation varied from two weeks to two years—the average being less than one month.

The circumference of the residual limb was measured in two different places and an average was computed. Below knee amputees were measured 2 inches and 4 inches below the medial tibial plateau. In above knee amputees, with the anterior superior iliac crest as the reference point, measurements were made at 4 inches and 7 inches distally.

Three different types of pressure bandages were used.

- Elastic Wrap.
- Elastic shrinker which is currently available on the market (Product 1[2]).
- A new elastic shrinker modified by the manufacturer depending on the efficacy of the compression (Product 2[1]).

We tested 6 different types of elastic shrinkers manufactured the same company. The final version was the one that met the following criteria:

- Pressure exerted was within the acceptable limits.
- Sustained pressure was applied for a long period of time.
- No change in pressure was noted with repeated washing.
- Acceptance by patients.

INSTRUMENTATION

A number of instruments are available to assess pressure applied to the skin.[2,8,14] The instrument we used for the measurement of pressure consisted of a pressure switch, a solid state pressure transducer (Microswitch, Honeywell, 120 PC Series), a liquid crystal readout in millimeters of mercury and associated electronic circuitry (Fig. 1). The pressure switch was similar to the pressure sensory described by Isherwood, et. al.[8] It consists of a flat silicone rubber envelope with internal switch contact. When the pressure on the envelope exceeds the pressure between the skin and stocking material, the contact separates and switches off an indicator located in the solid state pressure readout. At the instant the indicator is off, the pressure is read. We repeated this several times to obtain an average pressure reading. Four pressure sensors were attached to the residual limb; two on the anterior surface approximately two inches and five inches from the distal end of the limb, and the remaining two were located under the posterior surface at the same distances.

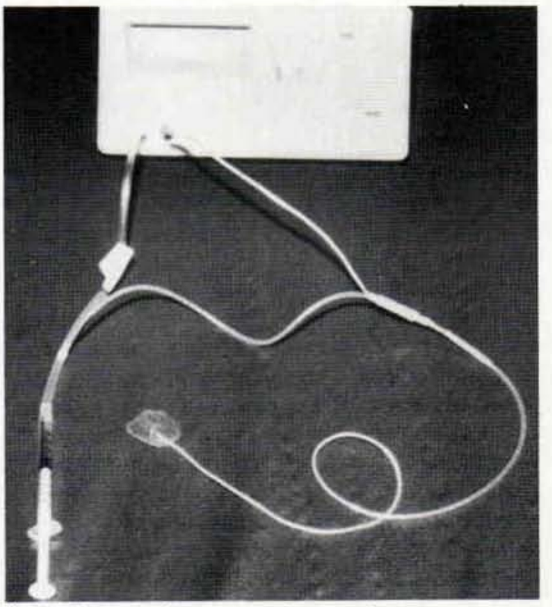


Fig. 1—Pressure instrumentation used to measure pressure applied to the skin by prosthetic bandages. The instrument consists of a pressure switch, a solid state pressure transducer and a readout in millimeters of mercury.

Fig. 2A – A single layer of elastic wrap is pulled over the limb and a plastic ring is pulled snugly against the skin.

The pressure under the elastic wrap was measured after application by both patient and staff. The pressure underneath the elastic shrinkers were measured under single layer and double layer wraps. (Figs. 2 A&B)

Pressure sensors underneath the new elastic shrinkers (Product 2) were in place for a long period of time and pressure was checked at periodic intervals. Pressures were also tested after repeated washings of the elastic shrinker.

RESULTS

The results of the pressure versus stump circumference measured with three different types of stump bandages are shown graphically in Figures 3, 4, 5, 6 and 7 namely: Elastic wrap, Product 1 (shrinkers 6" circumference) and Product 2 (6,8–10" circumference). The area between the two straight lines represents the acceptable limits of applied pressures. Figure 4 shows the pressure versus limb circumference for the elastic wrap on 13 patients for circumferences sizes varying from 15 to 65 millimeters of mercury with only 5 measurements in the ideal range.

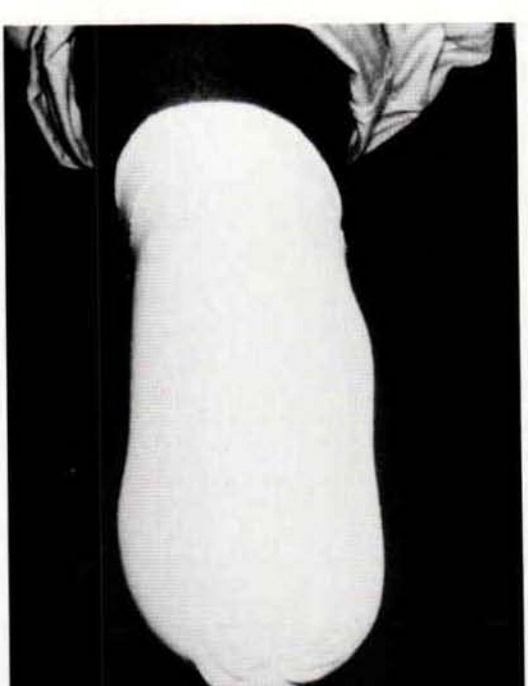
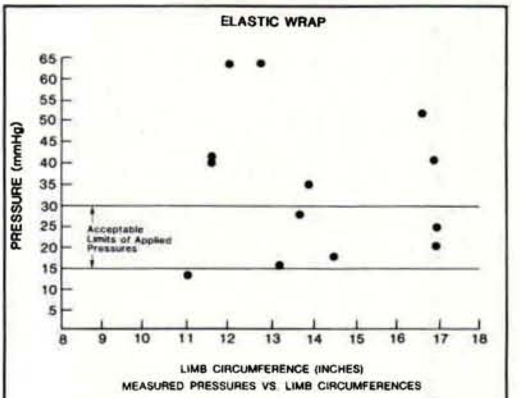


Fig. 2B – The wrap is then doubled back to provide two layers of compression.

Seven patients using the elastic wrap had pressure greater than 40 millimeters of mercury. There was a large difference in the applied pressure depending on whether the wraps were applied by skilled or unskilled persons. In follow-up measurements with prolonged usage, the elastic bandage tended to loosen and decrease the pressure exerted.

Figure 4 shows the average pressures measured with Product 1 on six patients. The residual limb circumference varied between 10 and 14 inches. As measured, a single layer exerted less than 10 mm/Hg over a 14 cm. residual limb. When doubled the same elastic bandage exerted pressure in the lower acceptable limits for only 3 patients and less in others.

Twenty patients were tested with Product 2 with shrinkers in single and double layers. In most, the pressures were below acceptable levels when a single layer was used, but when doubled 18 out of 20 showed an increase in pressure to within acceptable limits. Following repeated washing of Product 2, there was no decrease in the pressure exerted underneath the elastic shrinker. Figures 5, 6 and 7 show the results obtained with 6″, 8″ and 10″ unstretched diameter elastic shrinkers. The corresponding ranges of limb diameters are also shown on the figures.



MEASURED PRESSURES VS. LIMB CIRCUMFERENCES

Figure 3

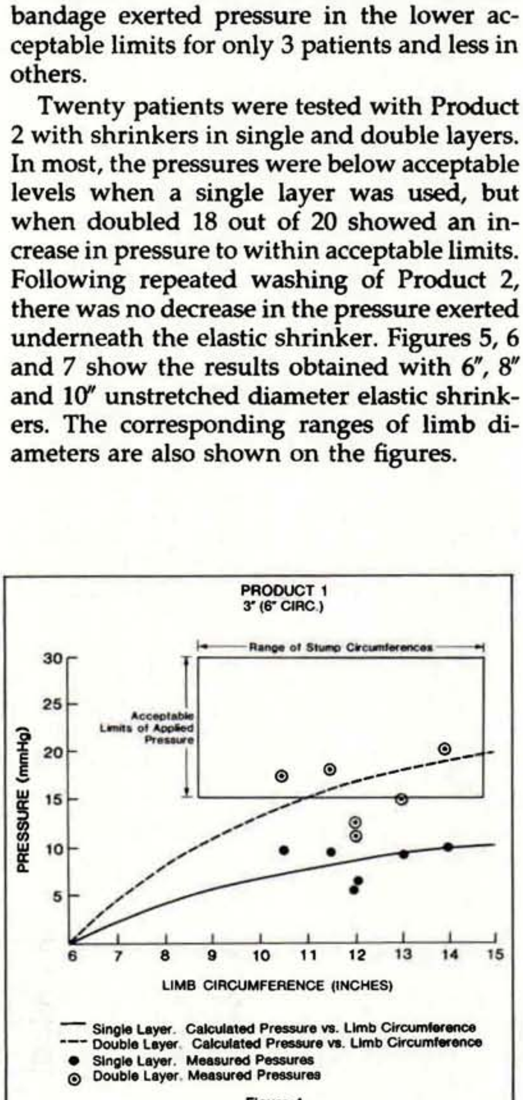


Figure 4

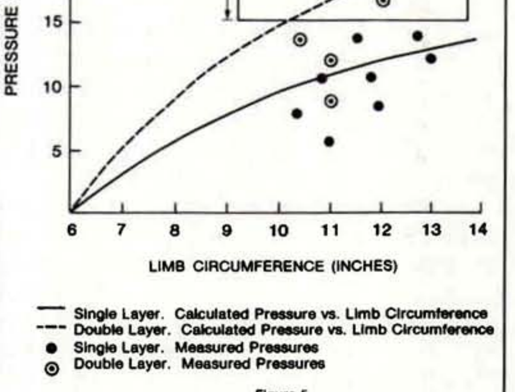


Figure 5

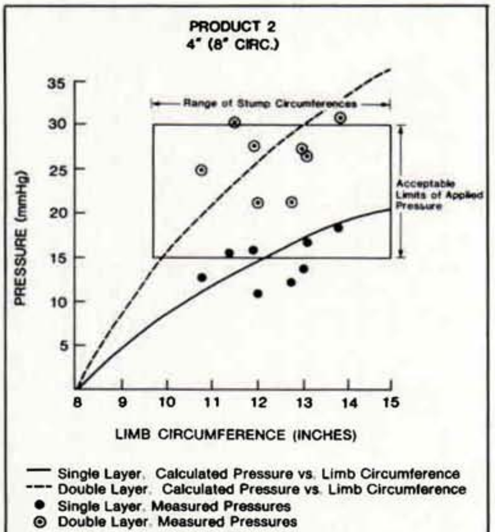


Figure 6

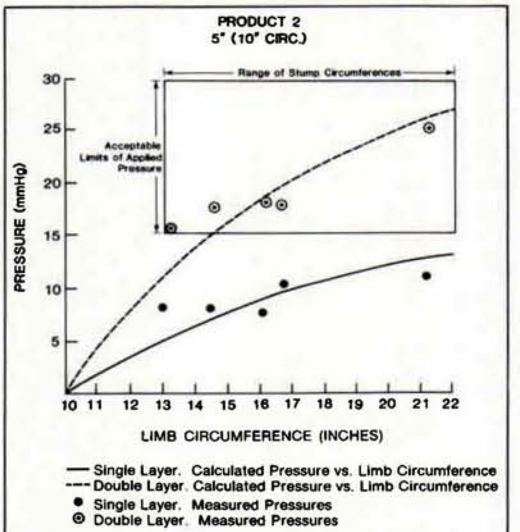


Figure 7

DISCUSSION

One of the important factors in edema control is equilibrium between the intra and extracellular fluid compartment.[16,17] At the arterial end of the capillary, the net forces favor exudation of fluid into the interstitial space with outward positive pressure of 7 millimeters of mercury. While at the venous end the net forces favor resorption of the fluid from the interstitial space in the venous capillary with a negative pressure 7 millimeters of mercury. Use of external compression can raise the extra-vascular hydrostatic pressure. This in turn decreases exudation of fluid at the arterial end of the capillary while increasing the resorption at the venous end. External compression also increases venous return. External pressure is especially important to control edema in an amputated limb which has virtually no muscle contraction to aid venous return.

A number of previous studies have examined the effect of external compression on venous return and reduction of edema. Allan Holloway, et. al., studied skin blood flow with Xenon clearance.[4] This study showed that the skin flow decreased when external pressure applied was less than 5 to 10 millimeters of mercury and also when pressure was above 30 millimeters of mercury. H. E. Groth, et. al. evaluated the effects of elastic stockings on saphenous and femoral venous flow by Doppler study.[3] Groth concluded that elastic stockings increase the venous flow velocity by 32 to 52 percent. Mueller, et. al. as quoted by Isherwood, studied the effect of elastic compression on femoral venous flow and concluded that the external pressure in excess of 0.04 kilogram per centimeter squared (25 millimeters of mercury) was potentially harmful.[8] Makin recommended an external pressure of 20 millimeters of mercury to be optimal.[10] Husni, et. al. showed that air splints inflated with 20 millimeters of mercury offered excellent compression in the lower extremity without compromising the venous circulation.[7] Several other studies,[9,11,12,19] all showed that external compression reduced edema. Based on these studies we concluded:

- Elastic compression helps in reduction of edema and increased venous return.
- External pressures of less than 15 millimeters of mercury are ineffective in increasing venous return but external pressures of more than 30 millimeters of mercury may cause harm. Therefore the

ideal pressure exerted by elastic compression stocking should be between 20 and 25 millimeters of mercury.

- The compression stocking should be capable of sustained pressure over a prolonged period of time.
- The pressure should be graded so that it should be more at the distal limb than the proximal limb.

The rigid dressing is still considered the most efficient method of reducing residual limb edema in the immediate post operative phase.[13] Unfortunately, use of the rigid dressing after amputation is not widely accepted by surgeons. It also requires a special team to provide the maximum benefit in its usage. Therefore, in spite of proven value, application of rigid dressing does not appear to be very popular. Wrapping the limb with an elastic bandage appeared to be the most convenient and perhaps the most popular method, but the elastic bandage has definite disadvantages as discussed above. The elastic shrinker tested in this study appeared to be easier for the patient to apply and, more importantly, to be more efficient in the reduction of edema. Manella, K. J. has also reported that elastic shrinker is more effective than the elastic bandage.[11]

Additionally, we found that with the "Compressogrip" the pressure was maintained for a long period of time and repeated washing did not affect the elasticity of the fabric used for the shrinker.

Based on our study the following are the advantages and disadvantages of the elastic shrinkers:

Advantages of Elastic Shrinkers

1. (a) With a temporary prosthesis during the night.
   (b) When rigid dressing can not be used.
   (c) When patient can not use permanent prosthesis due to repair or illness.
2. Ease of donning.
3. No special skills needed.
4. Pressure exerted close to ideal range.
5. Constant pressure over prolonged period of time.

Disadvantages of Elastic Shrinkers

1. Can be painful to apply and wear immediately post-operatively.
2. More expensive than the elastic bandage wrap.
3. Rolling of the elastic proximal border is a problem in A/K amputees.

SUMMARY

We have reviewed the literature to determine the ideal pressure to exert on residual limbs to successfully reduce edema. We tested the currently popular methods, measuring pressure under elastic bandage wraps and two types of elastic shrinkers. The elastic wrapping was shown to be less expensive than either of the elastic shrinkers. Pressures underneath the elastic wrap were found to vary widely depending on who applied the wraps. Both types of elastic shrinkers were easier to apply than the elastic wrap and any patient or family member could learn to apply these properly. Upon comparison there existed a significant difference in the pressure exerted between the types of elastic shrinkers used in this study. We therefore developed and recommended an elastic shrinker (Compressogrip) which exerts a pressure in the ideal range as demonstrated in this study.

Footnotes

[1]Knit Rite Corporation, Kansas City, Missouri (Compresogrip)
[2]Jobst Corporation

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