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Effect of elastic bandaging and prosthesis on the decrease in stump volume

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Objectives: The aim of this study was to compare the effect of elastic bandaging, pneumatic prosthesis, and temporary prosthesis on postoperative stump management.

Methods: This study included 14 patients, between 15 and 70 years old, whose causes of amputation were tumor, diabetes, Burger's disease, osteomyelitis, and traffic accident. Fifteen stumps in 14 patients, one of whom was bilateral, were evaluated. The elastic bandaging was applied for five stumps, the pneumatic prosthesis for five stumps, and temporary prosthesis for five stumps.

Results: A decrease in stump volume was observed for at least 2 or 3 weeks after the use of all three methods in patients who came to the Prosthetics and Orthotics Laboratory at Ankara University. The volume decrease induced by temporary prosthesis fitting was more significant than that achieved using elastic bandaging or pneumatic prosthetics ($p<0.01$). The greatest volume changes were identified distally for the elastic bandage group, proximally for the pneumatic group, and medially for the temporarily applied prosthesis group. The temporary prosthesis group took less time to permanent prosthesis (39 days) and required less prosthesis training ($p<0.01$). Three amputees in the elastic bandaging group had postoperative contractures.

Conclusion: Use of a temporary prosthesis results in ideal shaping of the stump in the shortest period of time. This approach also shortens the period of transition to permanent prosthesis, improves the quality of life of the amputee, and reintegrates the patient to normal life over a shorter period of time.

Key words: Amputation stumps; amputees; bandages; edema; prosthesis.

The factors that negatively affect wound healing of the stump after amputation include smoking, increasing hemoglobin, hematocrit values, malnutrition, diabetes, vascular problems, and the use of prophylactic antibiotics.[1-3]

From 1960 to the present day, many methods have been used to prevent stump edema and to shape the stump, although a consensus method remains elusive.[4] The main methods used to wrap the stump include the following: elastic bandage,[5] Unna's clothing,[6] polyethylene socket application,[7-9] semi-rigid methods including pneumatic applications, and rigid methods involving the use of a plaster socket.[4,10-12] In recent years, insertion of a cast into the silicon liner socket has become one of the most frequently used methods.

Money et al.[11] and Johnson[13] were the first to study the application of an elastic bandage to the stump. These studies indicated that the pressure applied by the elastic bandage is 20 mmHg.[14,15]

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During elastic bandage applications, even if early mobilization was possible, the amputated side was not loaded until the wound had healed.[4] However, rigid and semi-rigid stump-forming applications, as well as attempts to reduce edema, require load transfer.[4] The historical development of pneumatic applications has been related to problems encountered using a rigid dressing.[16-19] In practice, using general pneumatic mobility aids, which is started 1-4 weeks after the amputation, daily training does not exceed 1-2 hours a day and lasts 1-4 weeks. The pressure initially applied is 15-25 mmHg, but this value can be increased to 40 mmHg.[20] The most popular pneumatic application is the pneumatic post-amputation mobility (Ppam) method. Ppam involves the use of a cage, in which the pneumatic bag is settled, and a foot, attached to a pylon that is connected to cage, to facilitate walking.[17,21,22] Today, the equipment required for this method is designed by different companies, such as AMA, Saarbrücker, and Limp Tulip. For each type of construction, the joint is placed at the knee. In addition, there are a variety of systems with different names that utilize semi-rigid applications (e.g. Femurett, Halmstad and Haberman) involving plastic sockets that are narrowed using various techniques.[23]

The first applications of the plaster socket was immediate post-surgical fitting (IPPF) performed by Berlemont in 1961. This approach was continued by Weiss (Poland) in 1963 and by Burgess (USA) in 1964. This technique serves two main functions: the prevention of edema and transmission of the body's weight to the stump (by means of the pylon and foot, which are attached under the plaster socket and provide ambulation) starting from the first week of use. Even though this technique has certain advantages, such as the prevention of postoperative pain, edema, contracture and postoperative complications, and improves proprioception and desensitization education, there are also certain disadvantages. These disadvantages include confinement of the stump inside a humid environment for a long time, the inability to observe the stump from outside, and impracticality. Therefore, many patients elect to wear a removable plaster socket, which is applied a few days after amputation.[4,14-16,22,24-28] This technique, developed by Hughes et al.[29] in Australia, is considered to be quite practical by IPPF.

This study was carried out to prevent stump edema and to shape the stump by applying equal pressure in order to prevent postoperative complications such as contracture and wound injections. Through early mobilization, we sought to transmit weight to the stump and to shorten the transition period to the first prosthesis.

Patients and methods

In this study, 14 patients (6 women, 8 men; 1 bilateral, 13 unilateral) aged 15-75 years old and with body weights between 48-85 kg, were evaluated. Nine of the amputations were of the left and six were of the right extremity; nine of the amputees were transtibial (TT), and six of them were transfemoral (TF). TT amputee stump lengths were short in three of them, medium in three of them, and long in three of them; while the TF amputee stump lengths were short in two of them, medium in two of them, and long in two of them. Stumps were conical in shape in four patients, bulbous in three patients, and cylindrical in three patients. The causes of amputation were vascular diseases in seven patients (such as Burger's, diabetes), osteosarcoma in four patients, osteomyelitis in two patients, and traffic accident in one patient. Findings related to the patients and stumps are provided in Table 1. Of the 14 patients who arrived at our University Prosthetics-Orthotics Laboratory between 2 and 3 weeks after amputation between August 2005 and March 2008, elastic bandages were applied to five stumps, pneumatics to five stumps, and temporary prostheses (Fig. 1) to five stumps (three Hamstad (Fig. 2) and two Haberman). Perimeters of the stumps of patients (Fig. 3) were measured three times: on the day of admission to the hospital, and one week and two weeks after application.

The reduction of edema in each stump was calculated by taking perimeter and length measurements into account and measured by means of the water tank method or tape measure.[30] In our study, measurements were performed using a tape measure. The results obtained are shown in Table 2.

Statistical analysis

Data were analyzed statistically using the SPSS for Windows 11.5 package program. The data obtained were expressed with mean±standard deviation (SD) and minimum-maximum values. For the assessment

Table 1. Basic characteristics of patients and stumps.

Patient No.	Sex	Age (years)	Weight (kg)	Cause of amputation	Amputation level	Amputation side	Stump length	Stump shape
1	Female	70	60	Osteosarcoma	TF	Left	Long	Bulbous
2	Male	52	80	Burger's disease	TF	Right	Short	Bulbous
					TT	Left	Long	
3	Male	67	72	Diabetes mellitus	TT	Left	Short	Bulbous
4	Female	15	50	Osteomyelitis	TT	Right	Long	Conical
5	Male	26	64	Traffic accident	TT	Right	Medium	Bulbous
6	Female	15	48	Osteosarcoma	TT	Left	Medium	Bulbous
7	Male	70	50	Burger's disease	TT	Left	Short	Conical
8	Female	16	48	Osteosarcoma	TT	Left	Long	Conical
9	Male	21	70	Osteosarcoma	TT	Right	Long	Bulbous
10	Male	75	60	Diabetes mellitus	TF	Right	Medium	Cylindrical
11	Male	31	85	Osteomyelitis	TF	Left	Medium	Bulbous
12	Female	65	62	Diabetes mellitus	TT	Left	Medium	Cylindrical
13	Male	54	63	Burger's disease	TF	Left	Long	Conical
14	Female	60	70	Diabetes mellitus	TF	Right	Short	Bulbous

TF: Transfemoral, TT: Transtibial.

Table 2. Characteristics of elastic bandage, pneumatic prosthesis, and temporary prosthesis applications.

Case No.	Application type	Amputation date (day. month. year)	Time to the first prosthesis (days)	Training period (days)	Perimeter measurement I (cm)			Perimeter measurement II (cm)			Perimeter measurement III (cm)		
1	EB	28.07.2005	191	21	54	52	51	56	50	50	53	50	49
2	PP	23.03.2006	79	21	62	60	59	62	59	56	61	57	54
					47	44	43	46	42	41	45	41	40
3	PP	27.09.2006	37	18	36	32	31	35	31	30	34	30	30
4	EB	27.09.2006	64	17	30	28	29	29	30	27	29	28	26
5	EB	08.12.2006	58	17	35	34	33	35	33	33	35	33	32
6	TP	17.01.2007	45	15	38	33	30	37	32	28	36	30	28
7	PP	15.06.2007	32	21	47	32	29	38	32	28	37	31	28
8	TP	27.06.2007	20	15	38	36	34	35	32	32	33	30	29
9	TP	04.07.2007	54	15	58	57	54	55	53	53	54	52	52
10	PP	13.10.2007	40	21	70	62	53	70	61	53	67	58	49
11	TP	25.10.2007	28	17	73	62	49	70	58	47	68	57	45
12	EB	14.07.2007	89	21	38	32	29	36	31	28	35	31	28
13	EB	07.01.2008	107	23	56	50	41	55	50	41	55	49	40
14	TP	19.01.2008	46	17	67	56	50	66	55	49	64	53	47

EB: Elastic bandage, PP: Pneumatic prosthesis, TP: Temporary prosthesis.

of normally distributed data, t-test was used to compared two independent groups; for comparisons of more than two groups, one-way variance analysis and Bonferroni test were used. When data were not normally distributed, Mann-Whitney U-test and Kruskal-Wallis variance analysis were applied. Paired t-test was used to compare data of the first, second, and third measurements at proximal, middle, and distal areas. Statistical significance level was set at 0.05.

Results

Fifteen stumps' peripheral measurements, taken from proximal, middle, and distal areas, were recorded and evaluated. The greatest reduction in

edema was identified in the middle of the stump (Table 3) and in stumps involving temporary prostheses. For stumps that involved elastic bandages, the greatest reduction was observed at the distal end; for pneumatics, at the proximal end; and for temporary prostheses, in the middle portion. The reduction in edema at the middle of the stump averaged 1 cm in patients with elastic bandages, 2.6 cm in pneumatic applications, and 4.4 cm in patients with temporary prostheses. Differences between first, second, and third measurements from proximal, middle, and distal parts of the stump were found to be statistically significant ($p<0.01$) (Table 4).

Stump shape was bulbous in nine, conical in four, and cylindrical in two patients. Proximal, middle, and distal reductions in edema as a function of the shape of the stump are given in Table 5. Maximum reduction was observed in the middle of the bulbous stump (3.0 cm) and in the proximal of the conical (4.2 cm) and cylindrical stumps (3.0 cm).

There was no significant difference between women and men. Maximum edema was observed distally in both men and women reduction in stump (2.7 cm for women, 2.4 cm for men) (Table 6). For both sexes, the differences between first and third measurements were not significant ($p>0.05$).

The greatest reduction in edema was observed in the distal stump for TF amputees, (3.2 cm) and in the proximal stump (3.2 cm) for TT amputees. The difference between groups was not significant ($p>0.05$) (Table 7).

The greatest reduction in edema was measured in short stumps (3.6 cm). The reduction in edema was similar in medium and long stumps (2.8 cm) without any significant difference ($p>0.05$) (Table 8).

Transition to the first prosthesis required 38.6 days in the temporary prosthesis group, 47 days in the pneumatic group, and 102 days in the elastic bandage group (Table 9). Transition to the first prosthesis was earliest in the temporary prosthesis group, an average of 15 days earlier than in the pneumatic application group, and 63 days earlier than in the elastic bandage group. The significance between the temporary prosthesis group and the elastic bandage group was significant ($p<0.05$).

Training sessions with the first prosthesis were completed in 15.8 days (range 15-17 days) on average in the temporary prosthesis group, in 20.3 days (range 18-21 days) in the pneumatic application group, and in 19.8 days (range 17-23 days) in the elastic bandage group. The prosthetic training period was 4 days shorter in the temporary prosthesis group than for both pneumatic and elastic bandage groups ($p<0.01$) (Table 10).

Discussion

Studies have shown that cast socket applications (immediate postoperative fitting or removable rigid Dressing) prevent the formation of edema,[4,26,28,31,32] accelerate wound healing,[10,11,31,33-35] prevent knee flexion contracture,[4,36] shorten the transition period required for the first prosthesis,[4] and allow the amputee to regain walking ability in a short period of time.[6,34-37]

Wound healing studies on the effects of elastic bandages[31,38] and the pneumatic accelerator applications[20] are also available.

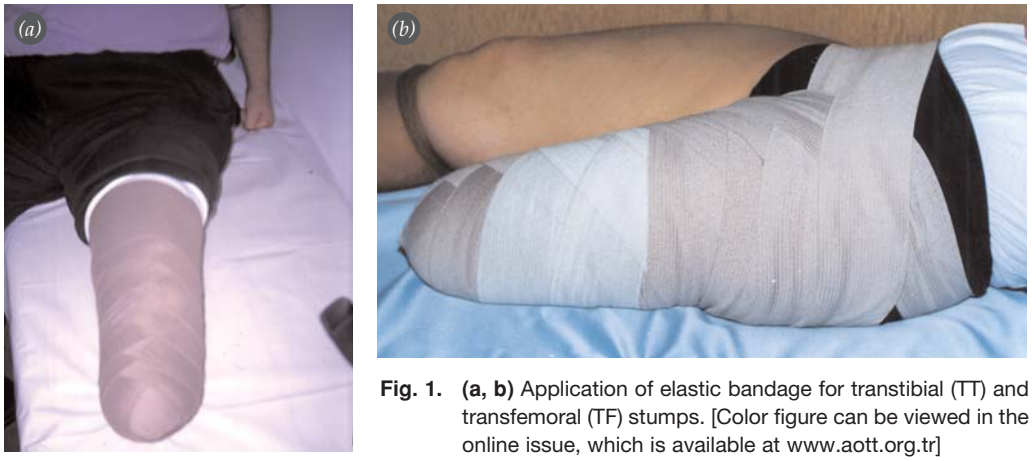

Fig. 1. **(a, b)** Application of elastic bandage for transtibial (TT) and transfemoral (TF) stumps. [Color figure can be viewed in the online issue, which is available at www.aott.org.tr]

Table 3. Reduction in stump edema (cm) according to applications.

Stump measurement	Application type	n	Mean±SD	Minimum	Maximum
Proximal	EB	5	1.2±1.1	0.0	3.0
	PP	5	3.6±3.6	1.0	10.0
	TP	5	3.8±1.3	2.0	5.0
Middle	EB	5	1.0±0.7	0.0	2.0
	PP	5	2.6±1.1	1.0	4.0
	TP	5	4.4±1.3	3.0	6.0
Distal	EB	5	1.6±0.9	1.0	3.0
	PP	5	2.8±1.8	1.0	5.0
	TP	5	3.2±1.3	2.0	5.0

EB: Elastic bandage, PP: Pneumatic prosthesis, TP: Temporary prosthesis.

Goldbranson et al.,[30] Manella,[39] and Mueller[40] showed that plaster socket applications, as compared with the elastic bandage, represent a more effective method for the prevention of stump edema. MacLean and Fick,[41] and Wong and Edelstein[6] reported that, compared with elastic bandage, pneumatic applications allow a more rapid transition to first prosthesis. However, the elastic bandage was not compared to temporary prosthesis applications. In our study, transition to the first prosthesis required 102 days in the elastic bandage group, 47 days in the pneumatic application group, and 39 days in the temporary prosthesis application group. Amputees that had received the elastic bandage began to use the first permanent prosthesis 55 days later than those who used the pneumatic prosthesis and 63 days later than those who received temporary prostheses. MacLean and Fick,[41] van Velzen et al.,[4] and Wong and Edelstein[6] reported that, compared with the pneumatic applications, the transition period to the first prosthesis was 2 times longer in elastic bandage group. However, we found that the duration of the transition period was extended 2.7 times in elastic bandage group.

Table 4. Statistical significance for the first, second, and third measurements from the proximal, middle, and distal stump.

Stump measurement	Measure I vs. II	Measure I vs. III	Measure II vs. III
Proximal	<0.05	<0.001	<0.001
Middle	<0.01	<0.001	<0.001
Distal	<0.001	<0.001	<0.001

Many studies have been carried out to investigate the difference between elastic bandage and plaster socket applications in terms of functionality and degree of independent living, but no difference has

Table 5. Reduction in stump edema (cm) according to stump shape.

Stump measurement	Stump shape	n	Mean±SD	Minimum	Maximum
Proximal	Bulbous	9	2.2±1.6	0.0	5.0
	Conical	4	4.2±4.3	1.0	10.0
	Cylindrical	2	3.0±0.0	3.0	3.0
Middle	Bulbous	9	3.0±1.3	1.0	5.0
	Conical	4	2.0±2.7	0.0	6.0
	Cylindrical	2	2.5±2.1	1.0	4.0
Distal	Bulbous	9	2.5±1.3	1.0	5.0
	Conical	4	2.5±1.9	1.0	5.0
	Cylindrical	2	2.5±2.1	1.0	4.0

Table 6. Reduction in stump edema (cm) according to sex.

Stump measurement	Sex	n	Mean±SD	Minimum	Maximum
Proximal	Female	6	2.5±1.5	1.0	5.0
	Male	9	3.1±3.1	0.0	10.0
Middle	Female	6	2.5±2.1	0.0	6.0
	Male	9	2.8±1.6	1.0	5.0
Distal	Female	6	2.7±1.4	1.0	5.0
	Male	9	2.4±1.6	1.0	5.0

Table 7. Reduction in stump edema (cm) according to amputation level.

Stump measurement	Amputation level	n	Mean±SD	Minimum	Maximum
Proximal	TF	6	2.3±1.6	1.0	5.0
	TT	9	3.2±2.9	0.0	10.0
Middle	TF	6	3.0±1.4	1.0	5.0
	TT	9	2.4±2.0	0.0	6.0
Distal	TF	6	3.2±1.5	1.0	5.0
	TT	9	2.1±1.4	1.0	5.0

TF: Transfemoral, TT: Transtibial.

Table 8. Reduction in stump edema (cm) according to stump height.

Stump measure	Stump length	n	Mean±SD	Minimum	Maximum
Proximal	Short	5	3.6±3.6	1.0	10.0
	Medium	5	2.6±1.8	0.0	5.0
	Long	5	2.4±1.9	1.0	5.0
Middle	Short	5	2.4±0.9	1.0	3.0
	Medium	5	2.8±1.8	1.0	5.0
	Long	5	2.8±2.6	0.0	6.0
Distal	Short	5	2.6±1.7	1.0	5.0
	Medium	5	2.4±1.5	1.0	4.0
	Long	5	2.6±1.5	1.0	5.0

been identified.[12,20,38] In our study, the reduction in edema in stumps treated with either elastic bandage or pneumatic and temporary prosthesis applications was not expected to affect the degree of functionality. The mean training period was 21 days (19-23 days) in the elastic bandage group, 17 days (range 15-21 days) in the pneumatic application group, and 12 days (range 7-16 days) in the temporary prosthesis application group. Baker et al.[31] reported that the cast prosthetic socket application shortens the period required for walking training (range 30-36 days) as compared to the elastic bandage application.

In our study, no patients required reamputation; however, infection was observed in one TT amputee (7%) and contracture in three amputees (21%) (flexion contracture of the knee in two patients and hip flexion and abduction contracture in one patient). These four amputees had received elastic bandages.

Fig. 2. Application of pneumatic prosthesis for a TF amputee. [Color figure can be viewed in the online issue, which is available at www.aott.org.tr]

Fig. 3. **(a, b)** Application of temporary prosthesis for a TT amputee. [Color figure can be viewed in the online issue, which is available at www.aott.org.tr]

Knee flexion contracture was reported by van Velzen et al.[4] in 10 amputees treated with the elastic bandage (19%).

The greater degree of edema reduction observed at the proximal stump (mean 2.6 cm) in the pneumatic application group suggests that internal pressure increased in this region during load bearing. Indeed, Scott et al.[42] reported that internal pressure during walking differed in patients who received Ppam and AMA pneumatic systems. In the elastic bandage group, the maximum reduction in edema (1.6 cm) was identified distal to the stump. This result shows that amputees treated with the distal-to-proximal eight-shaped coil technique could not effectively perform pressure adjustments. In the temporary prosthesis group, maximum reduction in edema (4.4 cm) was observed in the middle of the stump. Notably, thermoplastic sockets have yielded results that suggest that internal pressure concentrates in the middle of the stump during walking.

Edema is prevented through the use of the elastic bandage, and pneumatic and temporary prosthesis applications following TT and TF amputations. These applications also shape the stump. Furthermore, pneumatic and temporary prosthesis applications facilitate mobilization and load transmission to the stump dur-

Table 9. Transition period (days) to the first prosthesis according to applications.

Application type	n	Mean±SD	Minimum	Maximum
EB	5	101.8±53.1	58	191
PP	5	47.0±21.6	32	79
TP	5	38.6±14.1	20	54

EB: Elastic bandage, PP: Pneumatic prosthesis, TP: Temporary prosthesis. Mean±SD one desimal.

Table 10. Prosthetic training period (days) according to applications.

Application type	n	Mean±SD	Minimum	Maximum
EB	5	19.8±2.7	17	23
PP	5	20.3±1.5	18	21
TP	5	15.8±1.1	15	17

EB: Elastic bandage, PP: Pneumatic prosthesis, TP: Temporary prosthesis. Mean±SD one desimal.

ing the early stages of postoperative recovery. Although the number of cases is relatively limited, contracture and infection were not observed in any patient that received a pneumatic or temporary prosthesis. Temporary prosthesis allowed for the most rapid transition to the first permanent prosthesis and the shortest training period. These findings should be further verified by larger studies utilizing advanced measurement methods in the future.

Conflicts of Interest: No conflicts declared.

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