Wearing Behaviour of a Polyamide Matrix to Delivering Bioactive Principles in Dermatic Disorders

DACIANA-ELENA BRANISTEANU[1], GHEORGHE AGAFITEI[2], ION SANDU[3,4], OANA PARTENI[2], VASILICA POPESCU[2], MARIETA NICHIFOR[5], CEZAR-DORU RADU[2]*

[1] Grigore T.Popa University of Medicine and Pharmacy Iasi, 16 Universitatii Str, 7000115, Iasi, Romania
[2] Gheorghe Asachi Technical University of Iasi, 29 Mangeron Blv, 700050, Iasi, Romania
[3] Alexandru Ioan Cuza University of Iasi, Arheoinvest Interdisciplinary Platform, 22 Carol I Blv., 700506, Iasi, Romania
[4] Romanian Inventors Forum, 3 Sf. Petru Movila St., Bl. L11, Sc. A, III/3, 700089, Iasi, Romania
[5] Petru Poni Institute of Macromolecular Chemistry of Iasi, 41A, Grigore Ghica Voda Str., 700487, Iasi, Romania

Chronic venous failure (CVF) of leg, usually has as treatment a phlebotropic medication and the use of medicinal stockings with contention. Paper presents stages of performing of some knitted structures adjusted to the stage of CVF and to the leg conformation, as well performing of a polymer reservoir to control release of troxerutin, as an anti-phlebitic drug. In the framework of a clinic study has been accomplished tests of contention, gravimetric, photo colorimetric, washing and permeability related to patient observations from the clinic study. One focuses on mainly shifts of stocking performances into stage of wearing by patients with CVF.

Keywords: medicinal stockings, contention, phlebotrop, behaviour after wearing, transdermal diffusion, controlled release of the medicine drug

Paper presents manufacture of medicinal stockings with contention and controlled release of a drug to treat chronic venous failure of leg (CVF); one deals briefly with achievements elastic contention of knitted structures focusing on monitor stockings behaviour: after daily wearing and washing, respectively behaviour after grafting with polymer and medicine drug (troxerutin). It has been established reaction conditions for troxerutin grafting on polyamide-66 filaments of knitted yarns and a study in vitro for a phlebotrop diffusion, results are published elsewhere [1]. Figure 1 presents the basic scheme adapted after the Ringsdorf model of a drug grafted on a linear polymer structure to form a covalent polymer-drug conjugate.

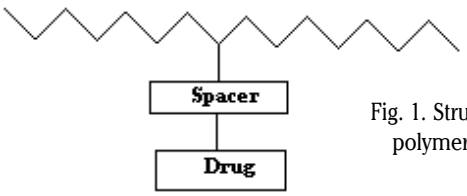

Fig. 1. Structure of a covalent polymer-drug conjugate.

The polymer can be a synthetic structure, and the spacer is obtained from a bi-functional reactive group with the role to obtain a distance of drug from the polymer in order to intensify its reactivity in subsequent hydrolysis processes or enzyme attack inside a physiologic medium. The bond between the polymer chain and spacer is biodegradable, being of ester, amide, carbonate, anhydride or urethane nature [1]. The polymer matrices have as criteria: -lack of toxicity and mutagenety; -biodegradability; -sterilization capacity. In the case of the paper the linear polymer is polyamide-66, the drug is troxerutin and the spacer is an acryloyl group. In figure 2 is illustrated chemical structure of troxerutin.

Treating the subject requires selection of patients and clinical monitoring of CVF evolution under oral phlebotrop medication (Detralex, 2 tablets/day), and/or therapy of contention with medicinal stockings and respectively with contention and phlebotrop grafted on yarn, in parallel with in vivo tests to characterize the permeation and tissue persistence of the phlebotrop, aspects which are presented collaterally in the paper.

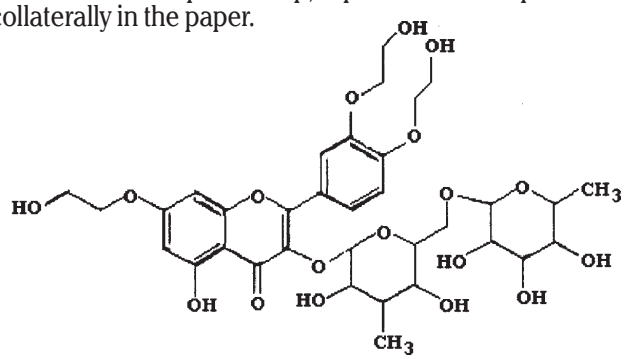

Fig. 2. Troxerutin (3',4',7-Tris [O-(2-hydroxyethyl)]rutin) structure

Named by people "varexes", CVF is a disease that has spread and it uses stockings with contention and phlebotrop medication as a therapeutical means to relieve discomfort caused by the sickness. The use of contention limits disease progression to severe forms, such as varicose ulcer, therefore, stockings should be worn all the life. Contention is the action of pressing the foot muscle due to tension exerted by the elastic stockings. Contention treatment is an irreplaceable therapeutical means [2-4], as recorded by Hippocrates and used by the Romans and Arabs.

Treatment consists of using medical stockings, the elastic dressings, oedema reducer or Unna boots. Favourable effects of contention are due to: -enhance venous and lymphatic circulation by increasing venous flow 5-7 times - reduce venous stasis in the veins of small size by increasing the oxygenation of tissues - decreased edema

* email: rcezar2010@yahoo.com

and extravasated protein absorption by promoting resorption in microcirculation due to increased tissue pressure - preventing phlebitis installation of CVF and skin lesions - amplify the effects of surgical treatment of varicose veins.

Designing and processing stockings

Stockings were designed by dermatologist prescriptions, which indicates level of contention (as value of pressure given in mm of Hg; 1mm Hg = 13,3Pa) gradually (fig. 3), at level of: joint, knee and calf according by disease stage. Dermatologist prescribes the number of stockings size, if the patient falls into dimensional standard sizes.

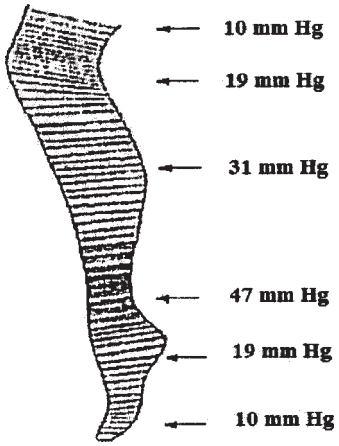

Fig. 3. An example of contention levels for a medical stockings

As a result of oedema caused by disease, patients often require customized stockings according to characteristic dimensions of the foot, the data being provided by the dermatologist.

One considers the maxim level of contention has to reach at the malleoli joint, in region of ankle contention diminishes at 40% and in knee area is a decrease of 70%. Heel and sole portion has the contention of normal stockings. One prefers not to affect the comfort of stockings use because the patient has to wear it all the life, daily.

The paper deals with the choice of yarn, knitted structure and finishing details and it is referring with stockings behaviour at wearing and washing.

To optimize the yarn characteristics were used as components, filaments of polyamide 66 as an element of strength, physical appearance, aesthetics and support to drug grafting and poly urethane filaments, Lycra type, as elastic component.

Were obtained elastic yarn types, which are precursors of some range of fineness and tensional characteristics by including the desired number of filaments, as follows:

Yarn I – polyamide 66 (pa 66)100%, textured – 44dtex f 34 ® 40den;

Yarn II – pa 66, 100%, textured – 78dtex f 34 → 70den;

Yarn III – blend 36dtex (25% Lycra 78dtex + 75 % pa 66 – 22 dtex f 34) → 32den;

Yarn IV – blend 52dtex (25% Lycra 78dtex + 75 % pa 66 – 44 dtex f 34) → 48den;

Yarn V – blend 72dtex (25% Lycra 156dtex + 75 % pa 66 – 44 dtex f 34) → 64den.

There were knitting thick stockings for cold weather and thin for summer time on Lonatti equipment. Using different looping depths were inserted for structures with tuck and float stitches, as well single jersey structures with specific level of contention adjusted to the disease stady [5]. One develops a technique for measuring and graphical analysis of contention after wear-wash cycles, which is communicated [6].

Manufacturing technology includes: *yarn lubrication*; *knitting*; *degreasing* using 1.5g/L surfactant (Perlavin RL 30), 20 min, at 60°C; *dyeing* at 95°C, 40 min, with acid dyestuffs (0.123% Telon Orange AGT, 0.044% Telon Rot AFG and 0,127% Telon Blau AFN, *levelling reagent* (2% Perigen LPA 2%) and acid reagent (1 g/L Peristal GAE) at *p*H = 5-5,5; *setting* shape with steam (pressure $1.2.10^5$ Pa) at 110°C for 2 s.

Stockings colour is pearl beige as the trend of the year. They were used for clinical tests on the response of leg with CVF to the action of elastic contention. Although no tests were performed on biocompatibility of dyestuffs, clinical observations did not show skin reactions to any of the patients in the study.

Intended for grafting stockings with medicine drug were used white stockings undyed - to avoid potential interference of dyestuff with medicine drug, they have processed according with above steps without dyeing stage, after the chemical grafting was performed.

Experimental part

Testing stockings from clinic study

It has been tested 10 pairs of stockings, size 5, after 30 days of wearing (minimum 12 h per day) and washing by the patients in clinical trials by experiments on contention, gravimetric, dimensional and colour. Patients followed instructions of a washing protocol using the same recipe: 3g/L non-ionic surfactants, immersed into washing solution 30 min to 40°C, hot and cold rinse, then drying in ambient conditions. For laboratory determinations dimensional gravity and stockings were conditioned at standard conditions. The data obtained are presented in table 1 (values of contention) and table 2 (dimensional and mass shifts). Contention measurements were performed on a Medical Salzmann device.

Tests on the influence of medicine application on stockings

Permeability to water vapor

Test of permeability to water vapour (according to standard BS 3424 part 34) considered in specialty terms „sweating test" was carried out in laboratories Labtest Intertek UK Ltd, subsidiary of Bucharest. Method consists

Table 1
CONTENTION VALUES AFTER STOCKING WEARING

Point of measuring	Initial contention of new stockings	Contention after wearing	Diminishing against initial value
	(mm col.Hg)	(mm col.Hg)	(%)
malleoli	30	19	-36.66
anckle	19	18	-5.26
knee	17	17	0.00
calf	15	14	-6.66
over calf	11	9	-18.18

Dimension/Location	Obtained values				Change (+ or -, %)
	(g) Initial	(g) After wearing	(10^{-3}m) Initial	(10^{-3}m) After wearing	
Total mass	107.982	102.893	-	-	-4.94
Length/joint	-	-	97 x 2	105 x 2	+8.24
Length/ankle	-	-	103 x 2	115 x 2	+11.65
Length/calf	-	-	111 x 2	124 x 2	+11.71
Length / stockings + bazon	-	-	82.8	85.6	+3.38
Length / stockings	-	-	60.1	61.6	+2.26
Note: multiplying with 2 of dimensional values indicate two legs of stockings					

Table 2
CHANGES OF MASS AND DIMENSIONAL VALUES OF MEDICINE STOCKINGS AT WEARING

	Vapour water permeability (VWP) Control	Fabric tested	Index of VWP	Difference between witness and medicine
	(g/m^2/24 ore)	(g/m^2/24 ore)	(%)	(%)
Witness sample	773.9	851.3	110.0	9.9
Sample with medicine	773.9	774.6	100.1	

Table 3
VALUES OF VAPOUR PERMEABILITY

of specially shaped cups filled with water, then they rotate 1 hour and finally are weighed. Again the cups are placed back in the equipment for 16 h then again weighed and difference is reported by calculating as grams/m^2/24 h.

Permeability decreases, as hygienic and physiological state, due to acryloyl type cross-linking agent as is illustrated in table 3, and values shown represent the average of ten determinations.

Kinetics of mass loss after washing of stockings with medicine drug

The behaviour of stockings was tested in laboratory with medicine drug in following washing conditions: it has been

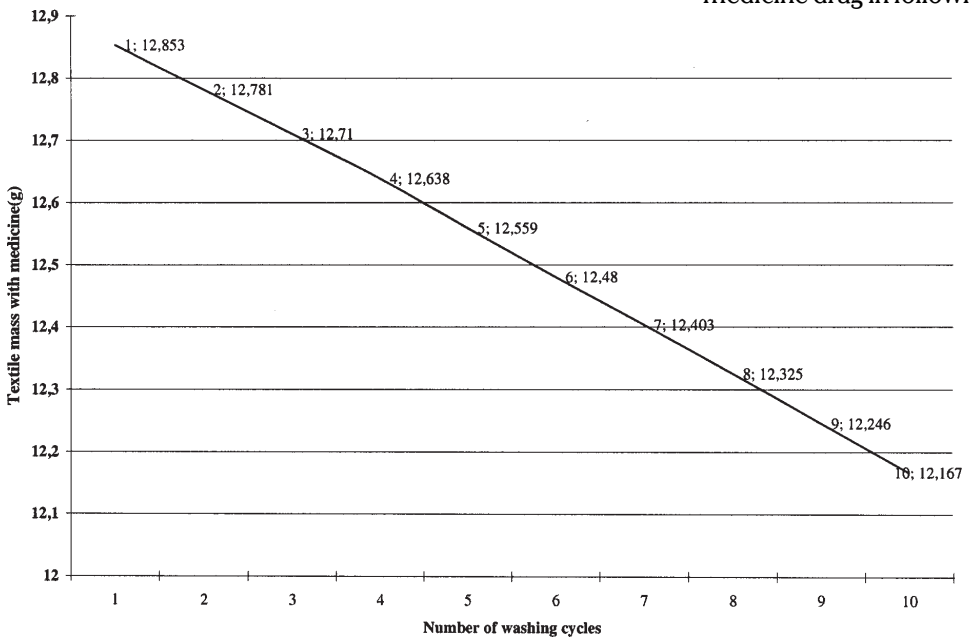

Fig. 4. Kinetics of mass loss for stockings with medicine during of washing cycles. *First digit in graph is the cycle number*

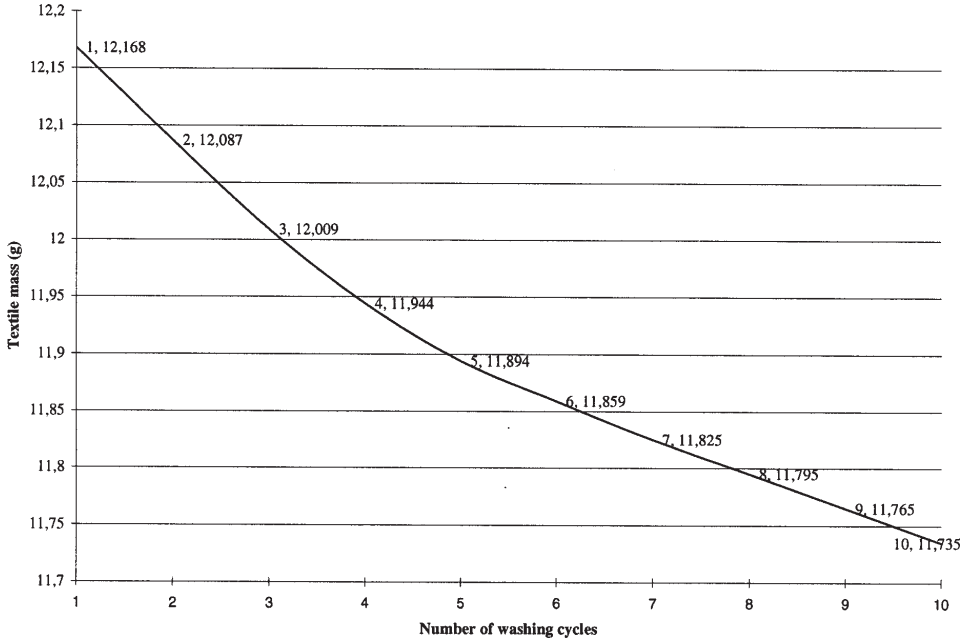

Fig. 5. Kinetics of mass loss for stockings during of washing cycles. *First digit in graph is the cycle number*

Table 4
VALUES OF COLOUR DIFFERENCE OF STOCKING WITHOUT AND WITH DRUG

Iluminant/ angle	ΔE (unit.AN)	ΔL (%)	Δa (unit.AN)	Δb (unit.AN)	ΔC (unit.AN)	ΔH (°)	Observations
D65/10	20.761	-3.122	-4.820	19.951	20.487	-1.244	M is darker, greener and yellower than A
A/10	18.380	-2.430	0.802	18.201	18.207	-0.649	M is darker. less green and yellower than
F11/10	22.715	-2.676	-2.384	22.431	22.524	-1.221	M is darker. greener and yellower than A
Standard (A) = White stockings ; Matching (M) = stockings with medicine grafted							

Legend: **ΔE** – colour difference between M and A (matching and standard in Adams Nickerson units); **ΔL*** – lightness difference between M and A (AN units); **Δa*** – variation red-green between M and A (AN units); **Δb*** – variation between yellow-blue between M and A (AN units); **ΔC*** – cromatic difference between M and A (AN units); **ΔH*** – hue difference between M and A (°).

Table 5
VALUES OF COLOUR DIFFERENCE OF STOCKING AFTER WASHINGS

Illuminant/ Angle	ΔE (unit.AN)	ΔL (%)	Δa (unit.AN)	Δb (unit.AN)	ΔC (unit.AN)	ΔH (°)	Observations
D65/10	4.963	-3.377	2.245	-2.861	-3.288	-1.554	*S* is darker. less green and less yellow than *M*
A/10	4.223	-3.290	1.442	-2.220	-2.111	-1.598	*S* is darker. redder and less yellow than *M*
F11/10	5.029	-3.384	1.826	-3.241	-3.397	-1.516	*S* is darker. less green and less yellow than *M*
Standard (M) = stockings with medicine; Matching (S) = stockings with medicine and then washed							

used a drum washing machine for 30 min at a speed of 10 rpm. with change of the direction of rotation at each 2 min and a washing solution with 3g/L nonionic surfactant 40°C. After each washing, drying was performed 60 min at 40°C, conditioning at 20 and 65% relative humidity and stockings were weighed. The test involves 10 washing cycles. The results obtained are shown in figure 4 for stockings with medicine grafted and in figure 5 for stockings without medicine; results represents the average of 5 tests.

Colour differences between white stockings and stockings grafted with medicine

As noted above, the initial stockings white (undied) is grafted [3] with troxerutin acryloyl inducing a specific colour yellow, as shown in the tests presented in table 4. Colour determinations were made at a DATA COLOR photo-colorimeter (2002) with software included to calculate the colour parameters [7-9].

Colour differences between stockings with medicine and stockings with medicine after 10 washing cycles

Values of colour differences obtained after 10 washing cycles are illustrated in table 5. Washing protocol is described above. The usual method to evaluate and computing is already wellknown and communicated in the literature [7, 10-12].

Results and discussions

Testing stockings from clinic study

After 30 days of wearing (by patients in clinical trials), the stockings contention have been changed because of the mechanical, thermal and chemical efforts to which they are subject and because of daily washing. Maximum decrease (table 1) appears in the region of malleoli. Thus, the lower region of leg in addition to stockings stretching acts as well frictional effort with shoes was intensified by reduced ventilation where temperature exceeds 45°C.

Sweat composition and *p*H changes: extensibility of knitted structure rheological behaviour of polyamide and elastic property of polyurethane

Influences presented add each-other, causing reduction of stockings contention. In the knee region contention does not change because the stockings permit good ventilation. the absence of sweating and mechanical applications. Towards the top of the stocking, temperature increases due to the decrease ventilation, plus the friction between the stockings and other items of clothing: trousers or skirt, these items reduced stockings capacity of contention.

The same factors act on dimensional modifications [13-19] as well as loss mass (table 2).

Stocking mass decreases by 5% compared to initial value and is due to fibre erosion by washing, but also because of the intense friction between stocking and shoe sole, as a result of pressure from body weight. In this area, after 30 days of wearing and washing some stockings show fractures. Overall, stocking structure is enlarged and elastic properties of knitted structure shrink in value. A patient for a period of one month requires two pairs of stockings for a contention closed to projected value.

Under the same conditions. stocking changes colour [7]; value of difference colour between initial stocking and that one which is worn and it follows the same change as the value of contention (table 1) and dimensional (table 2). The values obtained are communicated [2].

Influence of matrix textile at medicine application on comfort features

Initially, the stockings with contention are normally comfortable as everyday stockings. Clinical tests on 39 patients under treatment with oral phlebotrop and with stockings with elastic contention and had no comments on this issue. Subsequently, grafting medicine on polyamide structure, stockings handle is rougher. One does not avoid

roughness by using a softener in technological line does not reduce contention of stockings. However, the change in permeability (table 3) of about 10% shows a decrease in comfort, but the purpose of achieving the controlled release of a phlebotrop assumes the disadvantage reported. Patients in the group wearing with stockings grafted with medicine did not report worsening feeling of comfort being concentrated on the manifestations of CVF, which were significantly improved.

Kinetics of decrease mass of stockings with medicine as effect of washing

Tests determined the loss of a medicine chemically grafted on the polyamide product in the washing solution. At the initial mass of 12.250g of stockings untreated dry and conditioned by grafting added an average mass of 0.712g polymer and drug that reaches the mass of 12.962g stockings which means a loading degree of 5.812%. The value obtained was indicated by the dermatologist and is in agreement with in vitro determination troxerutin, which is released under the action of an aqueous solution simulating the composition and *p*H sweat calf [20].

From the initial batch were selected 5 patients wearing stockings with troxerutin and 10 patients wearing the same type of stockings, but without troxerutin. The first subset is the study group, the second is the control group which made a blind controlled study. One leg of the stockings was impregnated with troxerutin the second is the witness.

Each patient received impregnated stockings for foot right or left. which has the highest degree of vein damage. None of 15 patients was informed of the type of stockings they are wearing constantly, every day, not less than 12 h.

From figures 4 and 5 by washing, both stockings lose some of the initial mass. In figure 4 the mass loss is due to drug and fibre, and fibre loss in figure 5. The protocol for grafting of medicine is a final washing step with water and alcohol. which removes all drug unsetted on stockings. Allegedly stockings do not contain medicine unsetted. Initial mass of stockings grafted is 12.962g and 12.853g after the first wash; it means that 0.109g troxerutin, polymer and fibre is the lost weight. Stockings control (fig. 5) after the first wash loose fibrous mass 0.082g, as difference between 12.250 and 12.168g; thus, the difference between the two cases: stockings with medicine – stockings with medicine and then washed (12.962-12.853 = 0.109g) and respectively stockings - stockings washed (12.250-12.168 = 0.082g) is 0.027g. Theoretically, difference can be considered medicine diffused in the washing solution.

Comparing data from figure 4 and 5 is only qualitative because strictly by grafting fibre rheological change (with implications for loss of fibre in solution), and on the other hand. hydrophilicity of fibre grafted differs from fibre witness. Thus, under standard conditions stockings with medicine has got a regain different from that stockings control and hence errors at weighing.

In real conditions of wearing, transdermal diffusion of medicine initiated by specific enzymes and the presence of sweat takes place as a mechanism different from washing, kinetic mass decrease drug stockings having different causes and conditions are expected to present a specific shape. It is estimated that mass loss after 9 cycles of washing is less than 60% of the initial mass-drug polymer, a result outstanding corresponding to other communication where 50% of the drug is lost after the first wash. In real terms, the product is transferred from the sock not only in washing solution, as well as controlled release action while wearing.

Kinetics shows additional amount of medicine added to compensate drug loss by action of washing.

Analysis of colour parameters

A series of colour measurements (table 4) indicates that by grafting with drug initially stocking white colour become yellow; colour difference is $\Delta E = 20.761$ AN units due to the yellow component, mainly. Research having medical purposes did note obtain a certain colour, the appearance of colour produced being due solely to grafting medicine. According to the values presented in table 5, after washing, the colour difference between stockings with medicine washed 10 cycles is only 4.963 units AN. This indicates a relatively reduced colour lost which means that the medicine has a relatively good retention on stockings being released slowly over a longer period of wear. Colour measurements may be support for a dermatologist who can predict by seeing according with stockings colour if the patient have to wear anymore or to change stockings [7,13-19]. These issues require a detailed study.

Conclusions

Yarn made of polyamide-66 and Lycra used in structures with tuck and float stitches, as well single jersey structures function of looping depth achieve levels of contention differentiated according to medical prescriptions adapted to the stage of disease.

After everyday wearing and washing medical stockings loose some of the initial contention and change dimensions differentiated on leg length.

Grafting troxerutin to a control release drug determines a specific yellow colour stocking. a stiffening of stocking handle with a reduce comfort but the persistence effect of medicine on stocking is improved.

Corroborating clinical on influence of contention therapy and with a phlebotrop administered topically and orally with the tests performed on knitted structures offer a complete image on research results.

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