Basic Science Research

In Vitro Approach to the Dilative Behavior of Knitted Vascular Prosthetic Grafts

Nabil Chakfe,[1] Florence Dieval,[2] Lu Wang,[2] Fabien Thaveau,[1] Simon Rinckenbach,[1] Saleem Edah-Tally,[1] Daniel Mathieu,[2] Jean-François Le Magnen,[2] Gunnar Riepe,[3] Jean-Georges Kretz,[1] and Bernard Durand,[2] European Research Group on Grafts Used in Vascular Surgery (ERGGVS) Strasbourg and Mulhouse, France, and Coblence, Germany

The purpose of this report is to propose an in vitro approach to predicting the long-term dilative behavior of knitted polyester prosthetic grafts. Various techniques were applied to five warp knitted fabric prosthetic grafts in order to determine the following fabric properties: knitted fabric structure, textile structure, number and respective linear density of threads and strands, and length of yarn in each stitch. Following these investigations, the prosthetic grafts underwent testing to determine specific strength at break, breaking extension, and stress−strain curve. On two prosthetic grafts, image analysis was performed during circumferential tensile strength testing in order to monitor changes in structural features as a function of stress. Changes in the distance between two wales and two courses of stitches and stitch surface were measured. In addition to surface deformation, thickness was measured, using an induction sensor. Study of fabric structure showed many differences between the five models made by different manufacturers. Knit fabric structure was Indeforma in three cases and half-tricot in two. Strand number and size varied greatly from one model to another. Pattern also varied from one model to another, with knit stitch density varying from 1 to 3. Specific strength at break testing showed great differences in the mechanical properties of the grafts. These differences were especially obvious in the first part of the rheograms, which reflects the ability of the graft to comply in response to low-strength forces, i.e., much lower than those necessary to cause rupture. Image analysis of stitch behavior under stress further confirmed differences in graft behavior depending on the fabric structure adopted by the manufacturers. The in vitro approach proposed in this study to analyze the fabric characteristics of knitted prosthetic grafts effectively revealed differences in construction and behavior. These differences could account for differences in the dilative behavior of grafts in vivo.

INTRODUCTION

Polyester prosthetic grafts are the most widely used replacement conduits for vascular bypass, especially in cases involving reconstruction of middle-sized and large-diameter vessels. They may be made of woven or knitted fabric. Although all graft models have benefited from constant improvement, graft deterioration is still a potential source of complications.[1-3] The most frequent degenerative complication is dilation. Dilation can be diagnosed as a result of either coincidental discovery on a radiological image showing a localized or extensive graft defect or complications such as rupture, thrombosis,

Presented at the Sixteenth Annual Meeting of the Société de Chirurgie Vasculaire de Langue Française, Marseille, France, June 28, 2004.

[1]Department of Vascular Surgery, Strasbourg University Hospitals, Strasbourg, France.

[2]Textile Physics and Mechanics Laboratory, Textile Industry National School of Higher Education in Mulhouse, Mulhouse, France.

[3]Klinik für Viszeral- und Gefasschirurgie, Stiftungsklinikum Mittelrhein, Coblence, Germany.

Correspondence to: Nabil Chakfe, MD, Service de Chirurgie Vasculaire, Les Hôpitaux Universitaires de Strasbourg, BP 426-67091 Strasbourg, France, E-mail: nabil.chakfe@chru-strasbourg.fr

Ann Vasc Surg 2008; 22: 402-411
DOI: 10.1016/j.avsg.2008.02.001

Published online: May 8, 2008

or false aneurysm at the anastomotic site.[4,5] The incidence of dilation remains unclear due to lack of reliable epidemiological data and of systematic morphological evaluation of all knitted grafts implanted. Despite the constant efforts of manufacturers to improve graft safety, there are currently no tests or assessment techniques able to reliably predict occurrence of dilation after implantation of a given knitted graft.[6]

This report describes a novel approach for in vitro assessment of the dilative behavior of knitted polyester vascular grafts. The goal of this research is to improve understanding of the laws governing the behavior of different knitted textile structures and ultimately to develop a technique allowing prediction of long-term dilation with different graft structures.

MATERIALS AND METHODS

Prosthetic Grafts

The following five knitted vascular prosthetic grafts were studied:

- Dialine graft (DLG), manufactured by Cardial (Saint-Etienne, France)
- Gelsoft graft (GSG), manufactured by Vascutek (Inchinnin, UK)
- Microvel Double Velour graft (MDVG), manufactured by Meadox (Oakland, NJ)
- Cooley Double Velour graft (CDVG), manufactured by Meadox
- Polymaille graft (PMG) manufactured by Perouse Implant Laboratory (Bornel, France)

Mechanical tests were performed on uncoated grafts. When uncoated grafts were unavailable, coating material was removed using our standard cleaning technique involving soaking in gently stirred 10% sodium hypochlorite for 3 hr. After soaking, the prosthesis was rinsed with distilled water, treated with a 0.5% oxygen peroxide solution to neutralize hypochlorite residues, rinsed again with distilled water, and dried.

The following fabric characteristics were determined for each prosthetic graft: knitted fabric structure, textile structure, and number and respective size of threads and filaments. In addition, length of yarn per stitch was measured using a stitchmeter. Textile analysis was carried out in conformity with the recommended national and international standards (NF GO7-316 and ISO 7211-5).

Each textile structure was analyzed by measuring the number of stitch wales and courses per centimeter. Stitch density per square centimeter was determined by multiplying these two measurements. The mass of each stitch was determined by multiplying the length of yarn in each stitch by the corresponding thread size. The amount of material in each knit was determined by multiplying the stitch mass by the stitch density of the knit.

All data described in this report involve the standard knit accounting for 90% of the textile structure. Specific textile features related to remaking line and guide line were purposely not taken into account.

Circumferential Tensile Strength Testing

The prosthetic grafts were submitted to circumferential tensile strength testing (ISO/TC150/SC2WG3 standard), using a computer-assisted torque tensile strength tester. Maximum force at rupture, elongation at rupture, and stress—deformation curve were analyzed. The study was carried out using appropriate-sized clamps for the diameter of the prosthetic graft (Fig. 1).

Morphological Analysis of Knitted Fabric during Circumferential Tensile Strength Testing

Imaging analysis was carried out on two prosthetic grafts (DLG and PMG) during stress testing in order to observe structural features as a function of the applied force (number of stitches/cm^2). Changes in the distance between two stitch columns and between two stitch rows and the stitch surface were measured. In addition to measurement of surface deformation, thickness was measured using an induction sensor (Fig. 2).

RESULTS

Knitted Fabric Structure

Dialine graft. The basic DLG knitted fabric structure was indeforma. All filaments had a round cross section. Knitting was characterized by a combination of 2 and 1 lapping structure and 1 and 1 lapping structure. Threads in the 2 and 1 lapping structure were longer between loops and textured, thus giving a velour appearance to the surface of the prosthesis. Threads in 1 and 1 lapping structure were flat and less likely to work out of the textile structure. They ensured good overall mechanical performance of the graft. Textile structure analysis showed that the nominal diameter of the prosthetic graft had almost no influence on stitch distribution in the structure. The number of courses ranged from 24 to 26 per centimeter and the number of wales, from 18 to 19. Based on these figures, stitch density