

# 혈관 이식술 후 발생하는 혈관 폐색

김 동 익

성균관대학교 의과대학 삼성서울병원 혈관외과

TEL (02)3410-3467, FAX (02)3410-0040, E-mail: dikim@smc.samsung.co.kr

## I. 혈관 그래프트(Vascular graft)

### I-1. 서론

혈관그래프트(Vascular graft)의 발달사는 Table 1 에서 나타난 바와 같이 1906년 Carrel의 동물실험과 Goyanes의 임상적용으로부터 시작된다. 초창기 혈관그래프트의 개발은 비투과성을 지니면서 비생물학적 특성을 갖을수 있도록 하는데 초점을 두었다. 그러나 당시의 혈관그래프트는 결국 인체조직과 결합되지 못하여 봉합부위의 과열 및 색전 그리고 혈전등이 유발되었다. 1952년 Vinyon-N이 개발되면서 투과성을 갖는 직물혈관그래프트의 생성이 가능하게 되었고 1955년 혈관그래프트에 주름을 지게 만드는 기술이 개발되어 쉽게 휘어지면서도 탄력성을 갖는 직물혈관그래프트가 탄생하게 되었다. 현재 임상에서 사용되는 혈관그래프트는 Dacron과 polytetrafluoroethylene 재질이 가장 많이 사용되고 있다.

### I-2. 혈관그래프트의 이상적 조건

신체 모든 부위의 혈관에 대치할수 있도록 크기와 길이가 다양하여야 하며, 생체내에서 독성이나 이물 반응을 보이지 않으면서 장기간 개존성을 유지하여야 한다. 또한 탄력성을 갖고 이식후 혈관 상태에 따라 형태 변형이 가능하여야 하며, 쉽게 휘어지며, 봉합하기 쉬어야 하며, 마모되어 소실되지 않아야한다. 혈액과 접촉하는 내면은 매끈하여야 하며, 혈구성분에 손상을 주지않으며 세균감염에 저항성을 갖으면서도 항응고 기능을 갖어야한다. 그러나 이와 같은 많은 조건을 모두 수용할수 있는 혈관그래프트는 아직 개발되어 있지않다.

### I-3. 혈관그래프트의 생물학적 반응

혈관그래프트의 이식후 폐색을 유발시키는 원인은 첫째, 기존 질환의 진행에 의한것과 둘째, 혈관그래프트의 생체내 반응에 기인한다고 알려져있다. 생체내에 이식된 혈관그래프트는 봉합부위에 혈관내피세포 및 혈관벽세포로 구성된 pannus의 형성과 혈관그래프트 외부로부터 혈관그래프트 벽에 침투된 세포가 형질 변형 과정을 거치면서 혈관그래프트 내면에서 증식하여 위성내막비후를 초래하여 결국은 시기적인 차이를 두면서 혈관그래프트의 폐색을 유발시키게 된다. 이러한 혈관그래프트의 생물학적 반응은 주로 동물 실험을 토대로 연구가 진행되어 실제 사람에서 보이는 양상과는 다르다고 알려져

있다. 일반적으로 혈관그라프트 내부로의 섬유아세포의 침윤과 혈관내피세포의 이동과 함께 얇은 층의 형성은 혈전과 색전을 방지하고 내막증식을 억제하여 혈관그라프트의 폐색을 막을수 있다고 알려져있다. 이러한 일련의 과정을 "healing process of vascular graft" 라고 한다.

그러나 저자의 연구 결과는 기존의 생물학적 반응의 결론과 이견을 보이고 있다. 저자는 혈관그라프트의 외벽을 차단시킴으로서 혈관그라프트 내면에 발생하는 내막비후 현상을 억제할수 있었음을 보고하였다. 저자는 내막비후 현상의 원인 세포로 첫째, 혈액 내의 세포로부터 형질 변화에 기인한 것 둘째, 문합 부위를 중심으로 자기 혈관으로부터 혈관그라프트로의 혈관세포이동 셋째, 혈관그라프트 외부로부터 혈관그라프트 내부로의 세포 이동 및 형질 변형 그리고 증식에 기인한다는 가정하에 이중 세 번째 가정을 증명하고자 실험을 진행하여 혈관그라프트의 내막비후에 관여되는 주된 세포는 혈관그라프트 외부로부터 이동하여 온 혈관 평활근세포의 증식에 기인한다는 것을 밝혀 내었고, 이를 토대로 내막비후 억제를 위한 기존의 인공혈관을 개조하여 외부로부터의 세포 이동을 차단 시킬수 있는 새로운 혈관그라프트의 개발이 필요하다는 결론을 얻었다.

Table 1. History of Vascular Grafts

1906	Carrel	Homologous and heterologous artery and vein transplant in dogs
1906	Goyanes	First autologous vein transplant in man
1915	Tuffier	Paraffin-lined silver tubes
1942	Blakemore	Vitallium tubes
1947	Hufuagel	Polished methyl methacrylate tubes
1948	Gross	Arterial allografts
1949	Donovan	Polyethylene tubes
1952	Voorhees	Vinyon-N, first fabric prosthesis
1955	Egdahl	Siliconized rubber
1955	Edwards and Tapp	Crimped nylon
1957	Edwards	Teflon
1960	DeBakey	Dacron
1966	Rosenberg	Bovine heterograft
1968	Sparks	Dacron-supported autogenous fibrous tubes
1972	Soyer	Polytetrafluoroethylene (PTFE)
1975	Dardik	Human umbilical cord vein (HUCVAG)

#### I-4. 결론

다양한 재질의 혈관그라프트가 개발되어 임상에 적용되고 있으나, 아직까지도 이상적인 조건을 갖춘 혈관그라프트는 개발되지 않았다. 현재 혈관그라프트의 개발에 관련된 연구 과제로는 항생제를 접합시킨 혈관그라프트의 개발, 혈관내피세포를 접합시키거나 이들의 이동을 용이하게 하여주는 혈관그라프트의 개발, 혈관그라프트의 내막비후현상 억제법의 개발등이 많은 연구자에 의해 시행되고 있다.

## II. 동맥폐색증의 임상 증상과 혈관이식술

### II-1. 동맥폐색증의 종류 및 임상증상

1) 급성 동맥 폐색; 심방세동과 같은 심장 질환이 있는 경우에 심장에 붙어 있던 mural thrombi가 떨어지거나 대동맥벽에 붙어있던 thrombi가 떨어져서 발생한 색전에 의해 하지 동맥이 갑자기 막히는 경우로 심한 통증과 창백, 맥박소실이 유발되고 감각이 저하되면서 마비 증상이 유발된다(Table 2). 조기에 혈류를 재개통 시켜주는 치료가 요구되며, 혈전 용해술보다는 수술적 치료를 고려하여야 한다.

Table 2. Clinical categories of acute limb ischemia

Category	Description/prognosis	Findings		Doppler signals	
		Sensory loss	Muscle weakness	Arterial	Venous
I. Viable	Not immediately threatened	None	None	Audible	Audible
II. Threatened					
a. Marginally	Salvageable if promptly treated	Minimal (toes) or none	None	Inaudible	Audible
b. Immediately	Salvageable with immediate revascularization	More than toes, associated with rest pain	Mild, moderate	Inaudible	Audible
III. Irreversible	Major tissue loss or permanent nerve damage inevitables	Profound, anesthetic	Profound, paralysis (rigor)	Inaudible	Inaudible

2) 만성 동맥 폐색; 동맥경화증이 진행되면서 동맥혈관 내경이 서서히 감소되어 결국 완전 폐색이 유발된다. 이 과정에서 보상 반응으로 측부 순환(collateral circulation)이 발달되어 모든 예에서 조직 궤사를 유발하지는 않는다. 증상은 무증상으로부터 간헐성파행(intermittent claudication), 휴식시 통증(resting pain), 조직 궤사등의 순서로 악화된다(Table 3). 심한 간헐성파행 이상의 증상을 보이는 경우는 수술적 치료를 고려하여야 한다.

Table 3. Clinical categories of chronic limb ischemia\*

Grade	Category	Clinical description	Objective criteria
0	0	Asymptomatic—no hemodynamically significant occlusive disease	Normal treadmill or reactive hyperemia test
	1	Mild claudication	Completes treadmill exercise†; AP after exercise >50 mm Hg but at least 20 mm Hg lower than resting value
I	2	Moderate claudication	Between categories 1 and 3
	3	Severe claudication	Cannot complete standard treadmill exercise† and AP after exercise <50 mm Hg
II*	4	Ischemic rest pain	Resting AP <40 mm Hg, flat or barely pulsatile ankle or metatarsal PVR; TP <30 mm Hg
III*	5	Minor tissue loss—nonhealing ulcer, focal gangrene with diffuse pedal ischemia	Resting AP <60 mm Hg, ankle or metatarsal PVR flat or barely pulsatile; TP <40 mm Hg
	6	Major tissue loss—extending above TM level, functional foot no longer salvageable	Same as category 5

AP, Ankle pressure; PVR, pulse volume recording; TP, toe pressure; TM, transmetatarsal.

\*Grades II and III, categories 4, 5, and 6, are embraced by the term chronic *critical* ischemia.

†Five minutes at 2 mph on a 12% incline.

## II-2. 동맥혈관 우회술

1) 대치 혈관; 동맥우회술에 사용되는 대치 혈관으로는 자가정맥과 인공혈관이 있다. 일반적으로 직경 6mm이하의 인공 혈관의 경우는 우회 술식 후 개존율이 낮으므로 임상적으로는 6mm 이상만이 사용 되고 있다. 자가 정맥으로는 대복재정맥(greater saphenous vein)이 가장 많이 사용 된다.

2) 개존율 ; 하지 동맥의 경우 슬관절 상부와 하부에 따른 인공혈관과 자가정맥 이용에 따른 개존율에 대한 자료는 Table 4 와 Table 5에 요약을 하였다.

Table 4. Mean primary patency rates of combined series of above-knee femoropopliteal grafts. (Ann Vasc Surg 1990;4:309-312)

Graft type	1yr	2yr	3yr	4yr
Primary				
Reversed saphenous vein	84%	79%	78%	77%
In situ bypass	80%	76%	73%	68%
Secondary				
Arm vein	83%	83%	73%	70%
Human umbilical vein	77%	70%	61%	60%
Polytetrafluoroethylene	68%	61%	44%	40%

Table 5. Mean patency rates of combined series of below-knee femoropopliteal grafts. (Ann Vasc Surg 1990;4:309-312)

Graft type	1yr	2yr	3yr	4yr
Reversed saphenous vein	84%	82%	73%	69%
Arm vein	82%	65%	60%	60%
Human umbilical vein	82%	82%	70%	70%
Polytetrafluoroethylene	79%	74%	66%	60%

참고문헌)

1. Kim DI, Lee BB, Joh JW, Lee SK, Kim YI, Kim HH. Cells in pseudointimal hyperplasia is migrated from extravascular space. J Cardiovascular Surg 1997;38:277-281
2. Kim DI, Kambayashi J, Shibuya T, Sakon M, Kawasaki T, Mori T. Suppression of pseudointimal hyperplasia by a novel prostacyclin analogue: Beraprost. Surg Today 1995;25:722-728
3. Kim DI, Kambayashi J, Shibuya T, Sakon M, Kawasaki T. In vivo evaluation of DX-9065a, a synthetic factor Xa inhibitor, in experimental vein graft. J Atherosclerosis and Thrombosis 1996;2:110-116
4. Shibuya T, Kambayashi J, Kim DI, Kawasaki T, Shiba E, Sakon M, Mori T. Pseudointimal hyperplasia of ridged outer wall polytetrafluoroethylene vascular prostheses. Surg Today 1996;26:333-339
5. Shibuya T, Kambayashi J, Okahara K, Kim DI, Kawasaki T, Sakon M, Shiba E, Mori T. Subendothelial layer of pseudointima of polytetrafluoroethylene graft is formed by transformation of fibroblasts migrated from extravascular space. Eur J Vasc Surg 1994;8:276-285
6. Malone JM, Moore WS, Campagna G, et al. Bacteremic infectability of vascular grafts: The influence of pseudointimal integrity and duration of graft function. Surgery 1975;78:211

7. Sauvage LR, Berger K, Mansfield PB, et al. Future directions in the development of arterial prostheses for small and medium caliber arteries. *Surg Clin North Am* 1974;54:213
8. Sauvage LR, Berger K, Wood SJ, et al. Interspecies healing of porous arterial prostheses: Observations, 1960-1974. *Arch Surg* 1974;109:698
9. Scales JT: Tissue reactions to synthetic materials. *Proc R Soc Med* 1953;46:647
10. Allen BT, Reilly JM, Rubin BG, Thompson RW, Anderson CB, Flye MW, Sicard GA. Femoropopliteal bypass for claudication: vein vs. PTFE. *Ann Vasc Surg* 1996;10:178- 85.
11. Hunink MGM, Wong JB, Donaldson MC, Meyerovitz MF, Harrington DP. Patency results of percutaneous and surgical revascularization for femoropopliteal arterial disease. *Med Decis Making* 1994;14:71-81.

## Clinical Applications and Biological Behavior of Vascular Grafts

Donovan  
 Division of Vascular Surgery, Yonsei Medical Center,  
 Sungkyunkwan University, Seoul, Korea

### History of Vascular Grafts

1906	Carrel	Homologous and heterologous artery and vein transplant in dogs
1906	Goyanes	First autologous vein transplant in man
1915	Tuffier	Paraffin-lined silver tubes
1942	Blakemore	Vitallium tubes
1947	Hufuagel	Polished methyl methacrylate tubes
1948	Gross	Arterial allografts
1949	Donovan	Polyethylene tubes
1952	Voorhees	Vinyon-N, first fabric prosthesis
1955	Egdahl	Siliconized rubber
1955	Edwards	Crimped nylon
1957	Edwards	Teflon
1960	DeBakey	Dacron
1966	Rosenberg	Bovine heterograft
1968	Sparks	Dacron-supported autogenous fibrous tubes
1972	Soyer	Polytetrafluoroethylene (PTFE)
1975	Dardik	Human umbilical cord vein (HUCVAG)

## **Structural Classification of Vascular Grafts**

- **Vascular autografts**
- **Biologic prostheses of allogenic or xenogenic origin**
- **Composite biosynthetic macroporous prostheses**
- **Microporous synthetic prostheses**

### **I. Vascular autografts (composed of macroporous framework and a viable parenchyma that renders the wall impervious)**

#### **A. Venous autografts**

##### **1. Saphenous vein**

###### **a. Greater**

###### **b. Lesser**

##### **2. Arm vein**

#### **B. Arterial autografts**

##### **1. Internal thoracic artery**

##### **2. Radial artery**

##### **3. Internal iliac artery**

##### **4. Gastroepiploic artery**

##### **5. Inferior epigastric artery**



**II. Biologic prostheses of allogeneic or xenogeneic origin  
(composed of a chemically fixed, macroporous framework and  
a fixed, nonviable parenchyma that renders the wall impervious)**

**A. allogeneic venous grafts**

- 1. Umbilical vein**
- 2. Saphenous vein**

**B. Xenogeneic arterial grafts**

- 1. Bovine carotid artery**
- 2. Bovine internal thoracic artery**
- 3. Canine carotid artery**

**III. Composite biosynthetic macroporous prostheses (composed of  
a synthetic framework with macroporous interstices closed by  
a protein matrix)**

- A. Knitted or loosely woven Dacron prostheses combined  
with autogeneic fibrin-thrombus matrix deposited in  
preclotting for interstices closure**
- B. Knitted Dacron prostheses combined with a xenogeneic  
collagen-formalin compound deposited in manufacture  
for interstices closure**
- C. Knitted Dacron prostheses combined with a xenogeneic  
gelatin-formalin compound deposited in manufacture for  
interstices closure**
- D. Knitted Dacron prostheses combined with allogeneic  
albumin-glutaraldehyde compound deposited in  
manufacture for interstices closure**
- E. Nonwoven polyurethane structure combined with a  
xenogeneic gelatin-formalin compound deposited in  
manufacture for interstices closure**

**IV. Microporous synthetic prostheses (composed of a synthetic framework with tiny air-filled interstices that are so small that blood will not pass through them)**

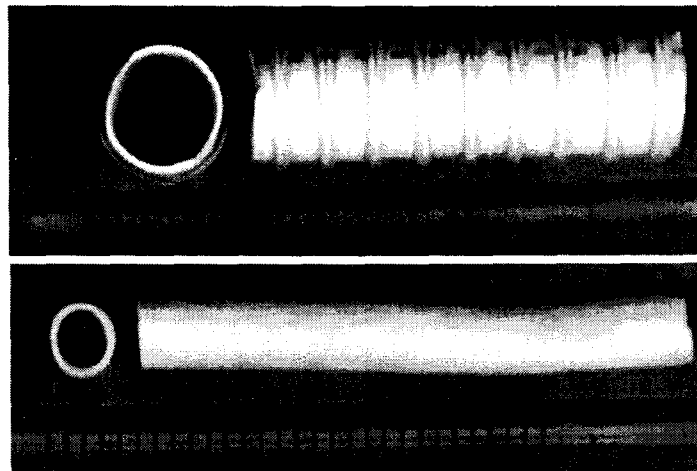
**A. Fabric(tightly woven Dacron)**

**B. Nonfabric**

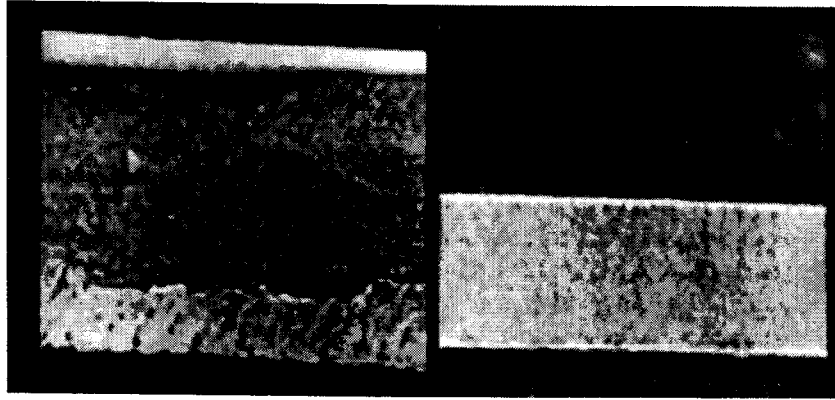
**1. Expanded PTFE(Teflon)**

**2. Polyurethane**

## **ePTFE Vascular Grafts**

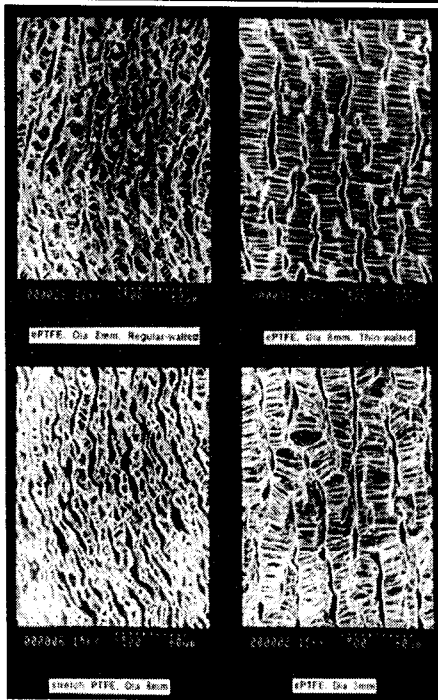


## SEM of ePTFE

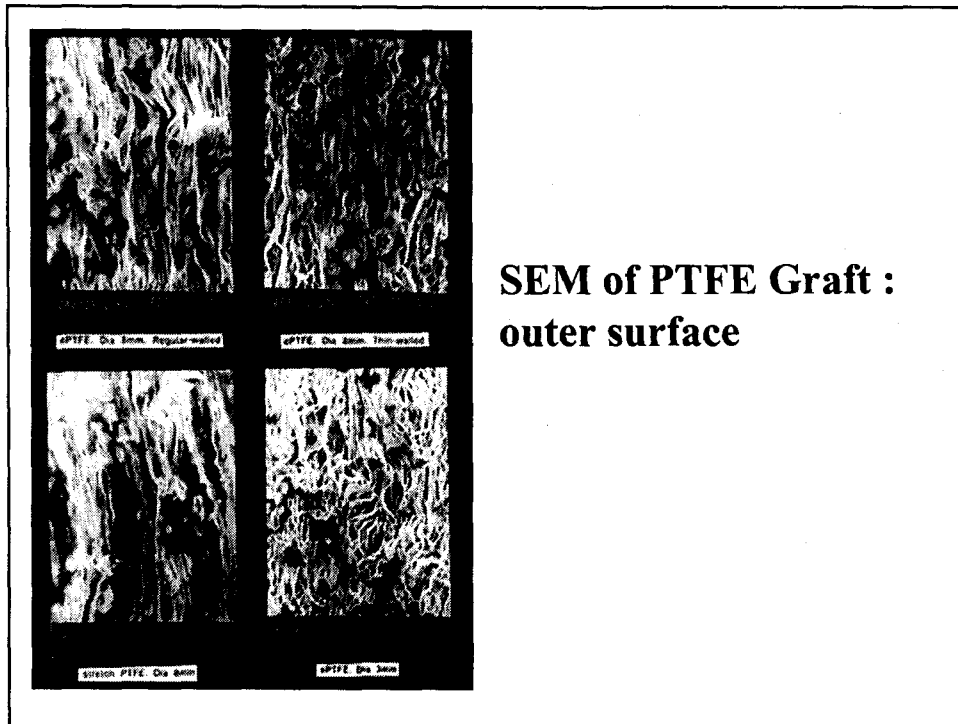


Regular wall

Thin wall

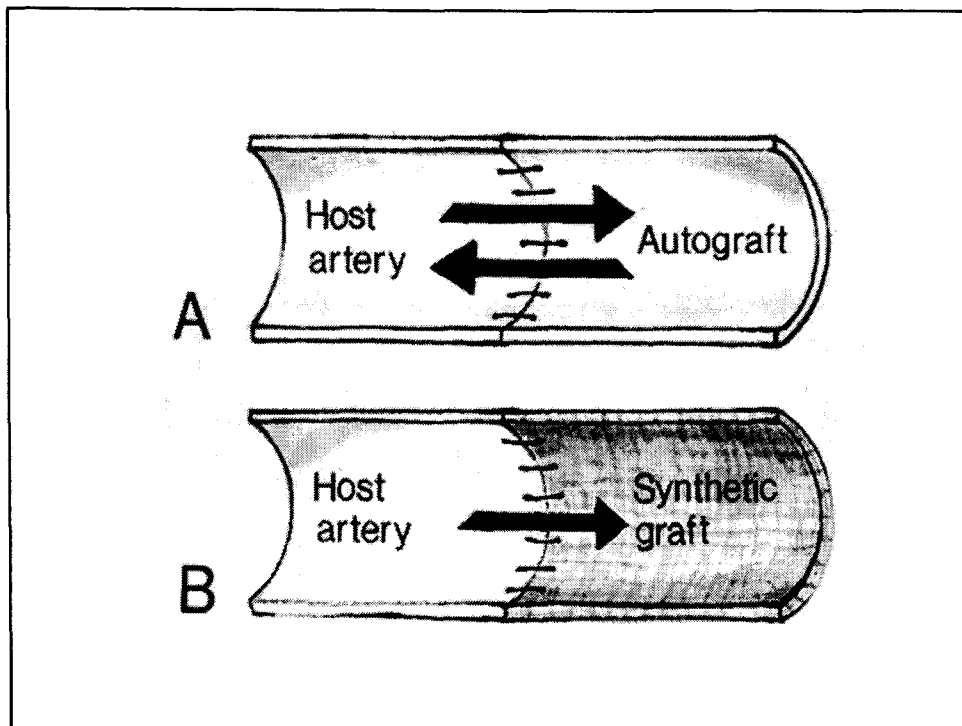


SEM of PTFE Graft :  
Inner surface



## **Healing capacity**

- **Reaction of perigraft tissue to outer wall**
- **Reaction of blood to inner wall**
- **Reaction of arterial wall at point of anastomosis**



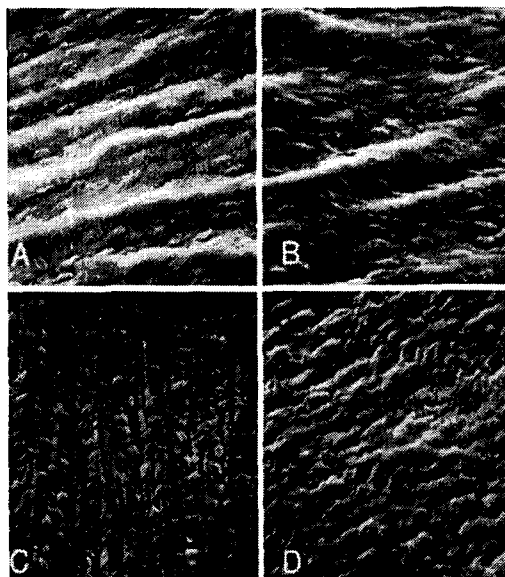
## **Healing capacity: integrity of anastomoses**

- **Autograft: independent within a few weeks on holding power of suture lines**
- **Nonviable graft: depend forever on holding power of suture lines**

## **Healing capacity: venous autograft in artery**

- **Adaptation: high pressure, pulsatile environment**
- **Process:**
  - 1) **Scattered endothelial cell loss**
  - 2) **proliferation & migration of endothelial cell**
  - 3) **Proliferation of cellular components**

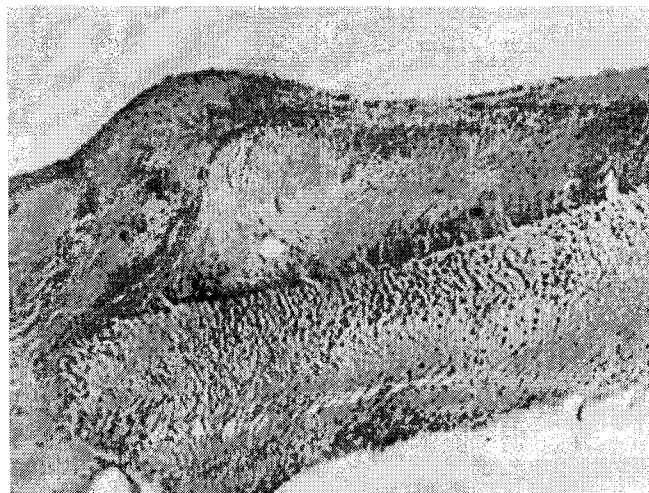
## **SEM findings of venous autograft**



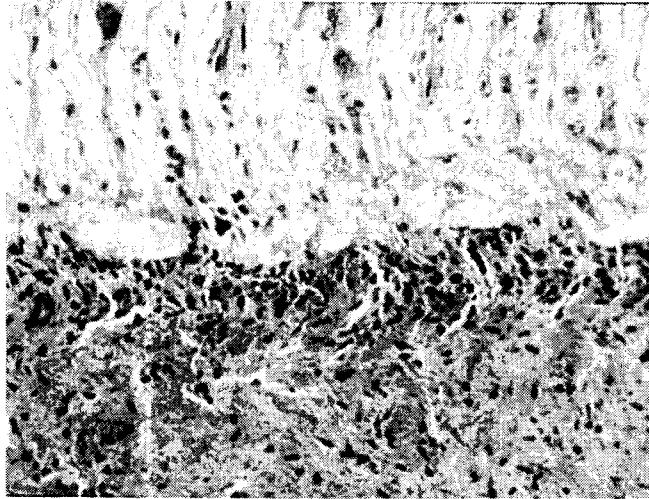
## **Healing capacity: Biosynthetic prostheses**

- **Ingrowth from perigraft areolar tissue : limited to adventitia**
- **Pannus ingrowth : limited to anastomosis**
- **Thin fibrin-thrombus layer**

### **Pannus Ingrowth**



## Ingrowth from perigraft areolar tissue



## Endothelial cell coverage of a PTFE graft

Group	Days after implantation	Endothelial cell coverage				Area of caudal anastomosis
		Area of cranial anastomosis	Cranial quarter area		Caudal quarter area	
			Middle area	area	area	
IVC	3	-	-	-	-	-
	7	++	+	-	+	++
	14	+++	++	+	++	+++
	28	+++	++	++	++	+++
Ao	3	-	-	-	-	-
	7	+	-	-	-	+
	14	++	-	-	-	++
	28	+++	+	-	+	+++

(-) : no endothelial cell growth, (+) : island of endothelial-like cell seen, (++) : endothelial cells extended moderately on the luminal surface, (+++) : endothelial cells extended completely on the luminal surface



## **Factor on Biologic Behavior of Vascular Grafts**

### **• Design Consideration**

- Host Factors**
- Anastomotic Factors**

## **Design Considerations**

- Suturability**
- Imperviousness**
- Thrombogenicity**
- Dimensional stability**

## **Suturability**

- **Determinant:**
  - 1) ease with which needle can penetrate the wall
  - 2) ability of wall to conform to vessel stoma
- **Factors:**
  - 1) thickness and compaction of framework
  - 2) interaction with host vessel

## **Imperviousness**

- **Definition:** loss of blood through the graft
- **Microporous:**
  - thightly-woven polyethylene terephthalate (Dacron)
  - polytetrafluoroethylene (Teflon, PTFE)
- **Macroporous:**
  - knitted polyethylene terephthalate (Dacron)
  - loosely-woven polyethylene terephthalate (Dacron)

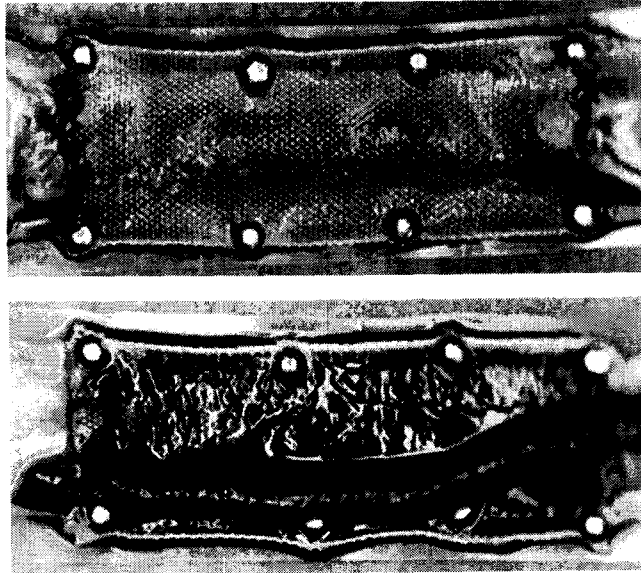
## **How to make imperviousness**

- **autograft:**
  - 1) **confluent cellular parenchyma and regenerative capacity**
- **macroporous prostheses:**
  - 1) **preclotting technique**
  - 2) **compound-bovine dermal collagen or gelatin or allogenic albumin**

## **Thrombogenicity**

- **Contact – activating capacity: platelets, leukocyte, factor XII**
- **Antithrombotic capacity: deactivate platelet**
  - neutralize thrombin**
  - lyse fibrin**
- **Endothelium: heparan sulfate, Heparin-like molecule**
  - thrombomodulin, prostacyclin,**
  - Antithrombin III, plasminogen activator,**
  - $\alpha$ -2 macroglobulin**

## **Dacron graft : thrombus**



## **Dimensional stability**

- **Arterial autograft: No thickening, no dilatation**
- **Venous autograft: thickened wall,  
resistant to aneurysm formation**
- **Prosthetic graft: fiber breakdown**

## **Factors on Biologic Behaviour of Vascular Grafts**

- **Design Consideration**
- **Host Factors**
- **Anastomotic Factors**

### **Host Factors**

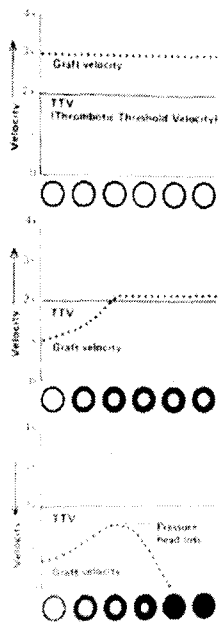
- Thrombotic potential
- Velocity of blood flow
- Atherogenic risk factors

## **Thrombotic potential**

- **Factors: number of platelet  
aggregation potential of platelet  
concentration of fibrinogen  
concentration of hematocrit**

## **Velocity of Blood Flow**

- **High blood flow: decrease platelet aggregation  
and fibrin formation**
- **Thrombotic threshold velocity (TTV):  
flow rate at which thrombosis begins**



• **High Velocity; above TTV**

**Little fibrin or platelet deposition, a clean surface persist**

• **Low velocity ; able to rise above TTV**

**Progressive fibrin build-up to uneasy equilibrium, with decrease of caliber to raise velocity just above TTV, but ever in danger of closure**

• **Low velocity ; unable to rise above TTV**

**Progressive fibrin build-up to closure due to critical loss of pressure-head as caliber decreases preventing increase of velocity**

## Atherogenic Risk Factors

- **Hyperfibrinogenemia**
- **Low level of HDL**
- **High level of LDL**
- **Hypertension**
- **Diabetes**
- **Smoking**

## **Factors on Biologic Behaviour of Vascular Grafts**

- **Design Consideration**
- **Host Factors**

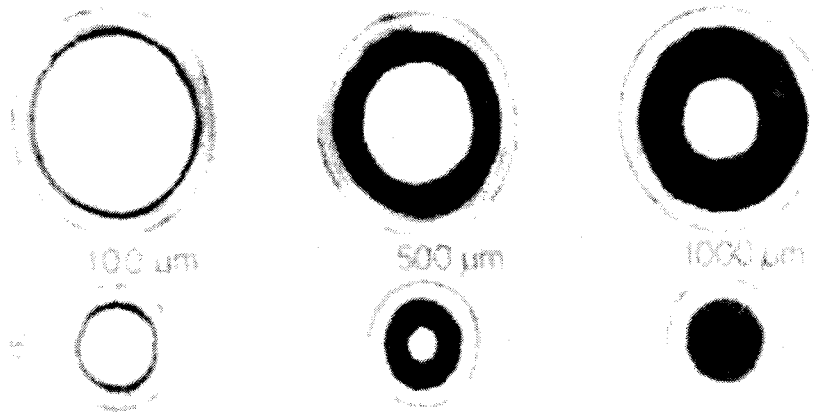
### **• Anastomotic Factors**

### **Anastomotic Factors: Type**

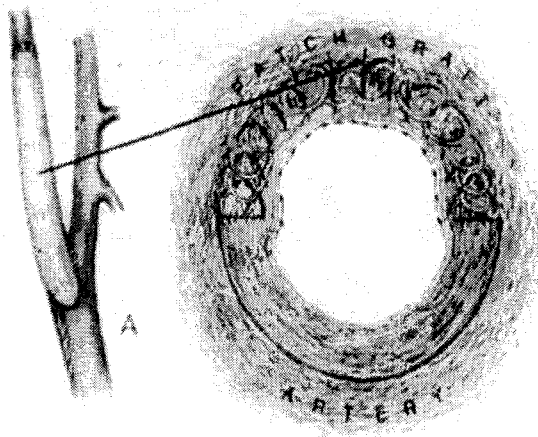
- **patch grafts**
- **end – to – end**
- **end – to – side**
- **side – to - side**



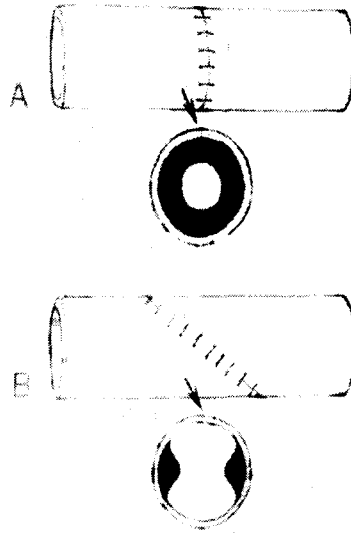
## Luminal narrowing



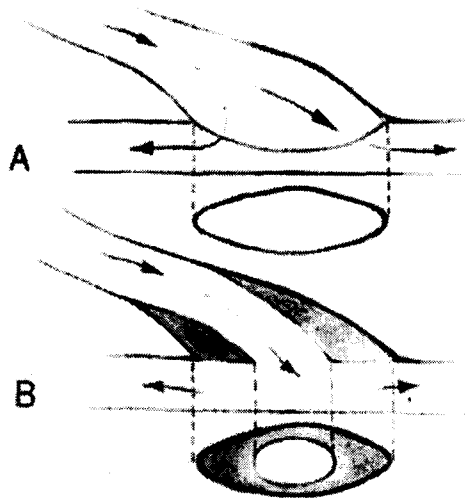
## Patch grafts



## End-to end anastomosis

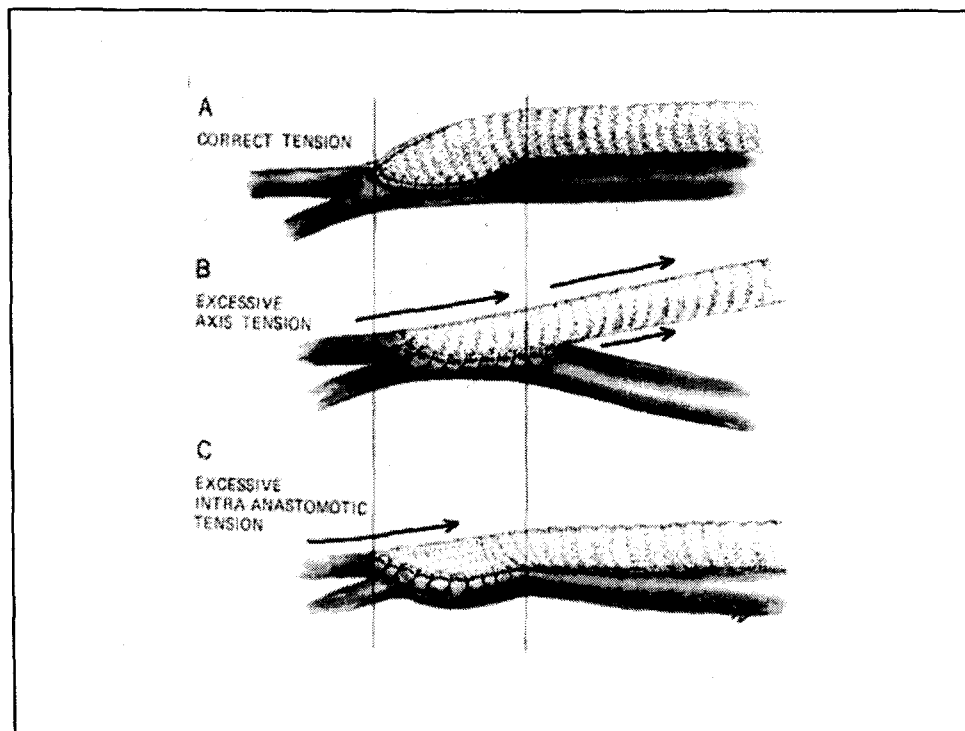


## Side to side anastomosis



## Anastomotic Factors: Longitudinal Tension

- **Excessive tension: forming a false aneurysm**



## **How to improve the graft patency**

- **Thrombus**
  - 1) **antithrombogenic agent**
  - 2) **graft modulation**
- **Intimal hyperplasia**
  - 1) **suppression of VSMCs proliferation**
  - 2) **graft modulation**

## **Items of Study**

- **Identification of differentially expressed mRNAs of vein graft after arterial bypass**
- **Tissue Engineering of Vascular Prosthetic Grafts using Autogenous Vein Cells**

Identification of differentially expressed  
mRNAs of vein graft after arterial

b



Division of Vascular Surgery, Brigham Young University Medical  
Center, Salt Lake City, Utah 84143

## Introduction

- **Intimal hyperplasia is characterized by the vascular smooth muscle cell (VSMC) proliferation in the intima and subsequent accumulation of extracellular matrix.**
- **A variety of factors that might be considered as possible VSMC mitogens induce the specific gene expression of VSMC.**

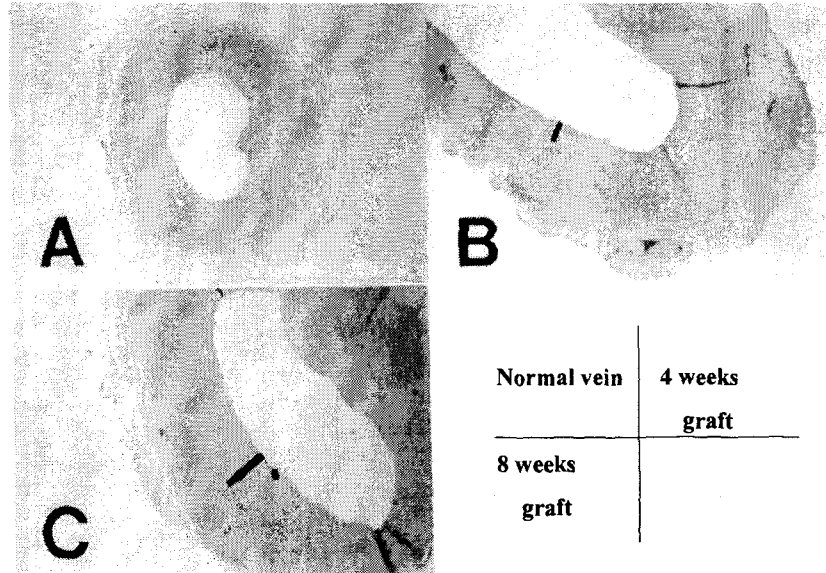
## **Purpose**

**This study was designed to identify the differentially expressed mRNA of the autogenous vein graft after arterial bypass by using a method of mRNA differential display.**

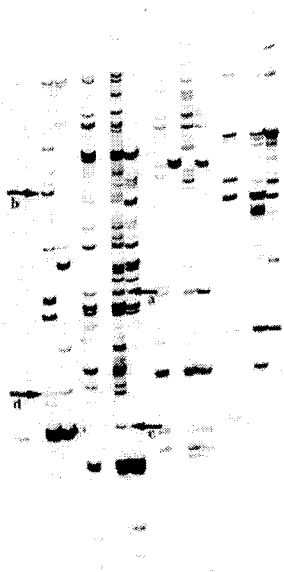
## **Animal Model**

- **Bilateral femoropopliteal reverse saphenous vein bypass was performed on both hind limbs of a Mongrel dog(n=8).**
- **At 4 weeks (n=4) and 8 weeks (n=4) after the implantation, the vein bypass graft were harvested.**

## Histological Analysis: intimal hyperplasia



Oligo dT primer	H-T <sub>11</sub> A			
Arbitrary primer	H-AP1	H-AP2	H-AP3	H-AP4
RNA	1 2 3 4	1 2 3 4	1 3 3 4	1 2 3 4



### Differential Display of Amplified cDNA :

Primer (H-T11A/H-AP1,2,3,4)

Lane 1; normal artery

Lane 2; normal vein

Lane 3; 4 weeks graft

Lane 4; 8 weeks graft

a: chymase gene

b: PDGFRL gene

c: ATQ1 gene

d: Calcineurin gene

## Summary of DDRT-PCR

3' P	5' P	NA	NV	4 wk	8 wk	Gene
H-AP2	H-T <sub>11</sub> A	+	-	+	-	Chymase
H-AP3	H-T <sub>11</sub> C	+	-	+	-	QK1-5B
H-AP7	H-T <sub>11</sub> C	+	-	+	-	Frzb
H-AP6	H-T <sub>11</sub> A	+	-	-	+	TIMP-3
H-AP2	H-T <sub>11</sub> A	-	-	+	-	ATQ1
H-AP2	H-T <sub>11</sub> C	-	-	+	-	ATQ1
H-AP4	H-T <sub>11</sub> C	-	-	+	-	Cyclin A-3
H-AP7	H-T <sub>11</sub> C	-	-	+	-	LIV-1
H-AP1	H-T <sub>11</sub> A	-	-	+	-	PDGFRL
H-AP7	H-T <sub>11</sub> A	-	-	-	+	TPRD III
H-AP1	H-T <sub>11</sub> A	-	-	+	+	Calcineurin

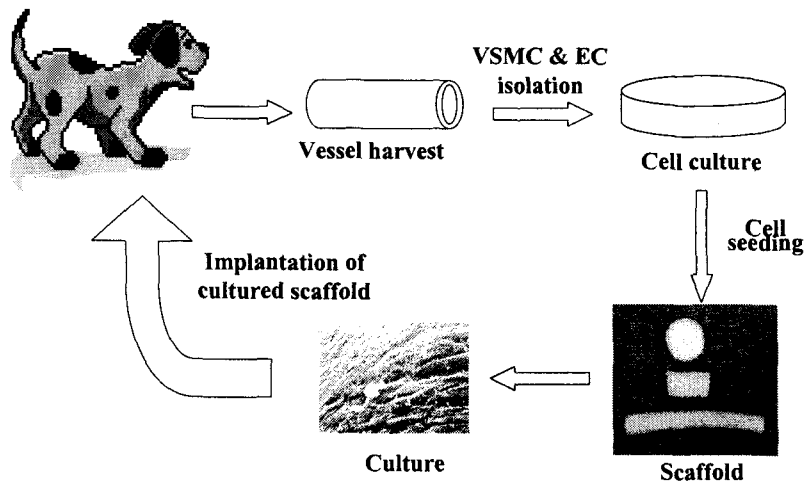
3' P; 3' primer, 5' P; 5' primer, NA; normal artery, NV; normal vein  
4wk; 4weeks graft, 8wk; 8weeks graft

## Tissue Engineering of Vascular Prosthetic Grafts using Autogenous Ves

*Div. of Vascular Surgery, Samsung Medical Center,  
Sungkyunkwan University School of Medicine Seoul, Korea*



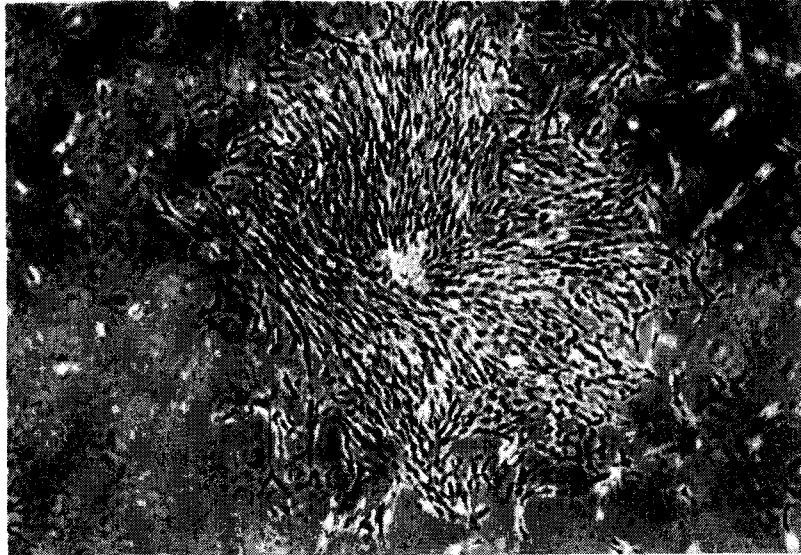
## Schematic illustration of tissue engineered vascular graft implantation



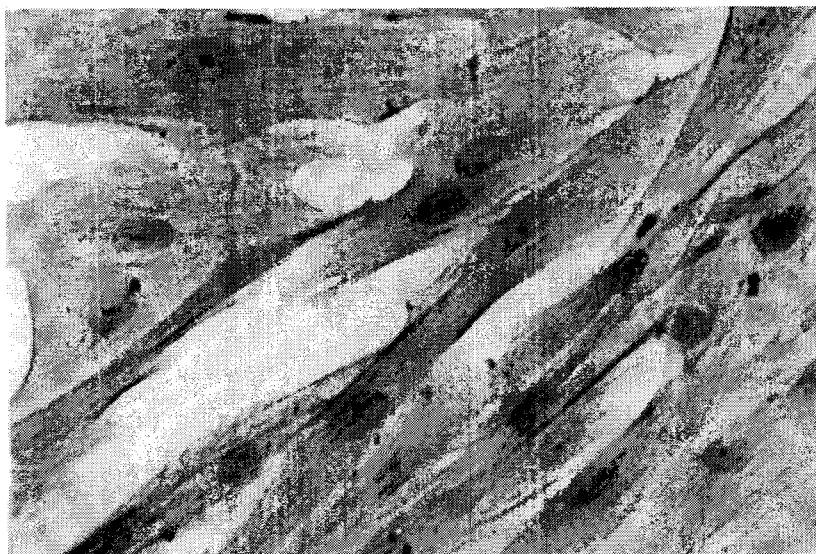
## Problems in tissue engineered vessel

- Time for incubation of cells
- Mechanical aspects of scaffold
- Changes of cell properties
- Graft patency

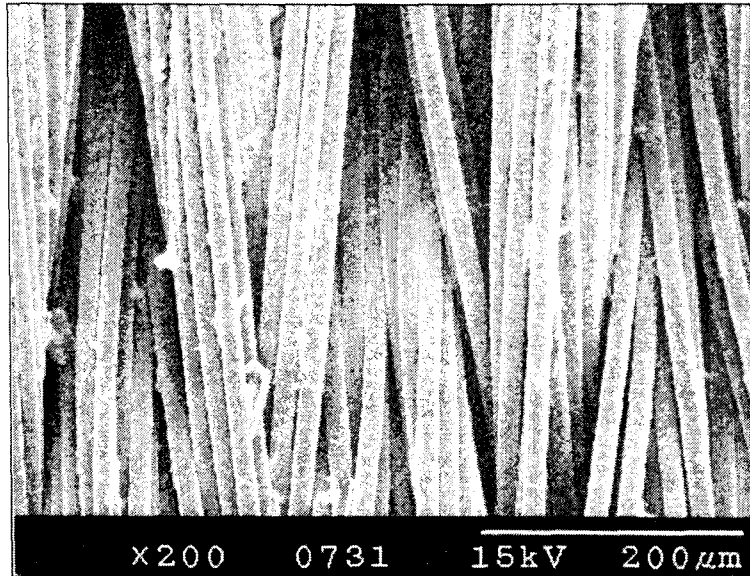
**Primary culture of VSMCs : 2 weeks**



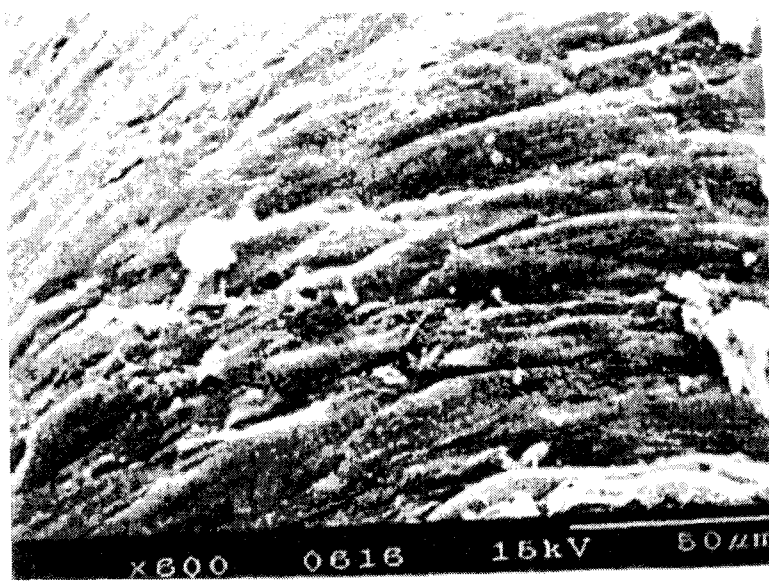
**Primary culture of VSMCs : immunohistochemical staining using by  $\alpha$ -actin antibody**



**Scanning electron microscopy : mesh PLGA scaffold**

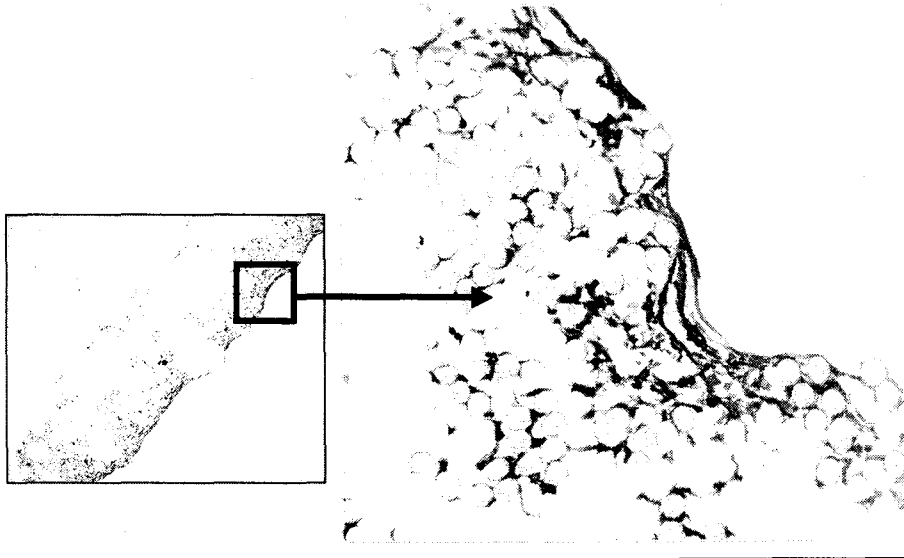


**Scanning electron microscopy of seeded mesh PLGA scaffold : 4 weeks**

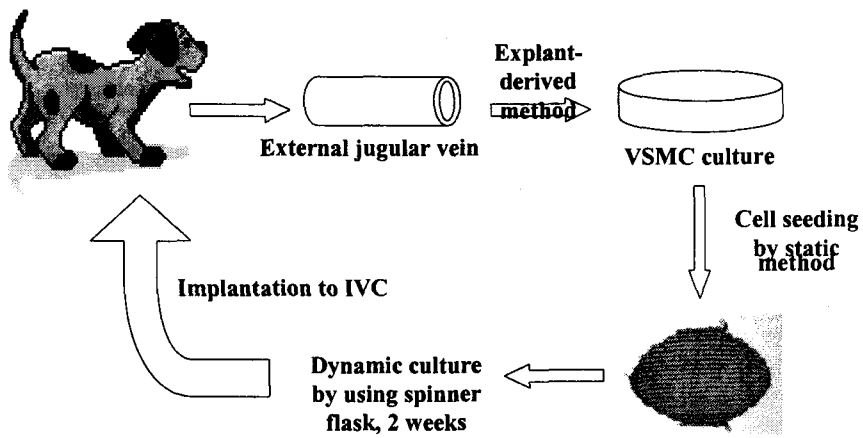


**VSMCs within the mesh PLGA scaffold ( 3 weeks):**

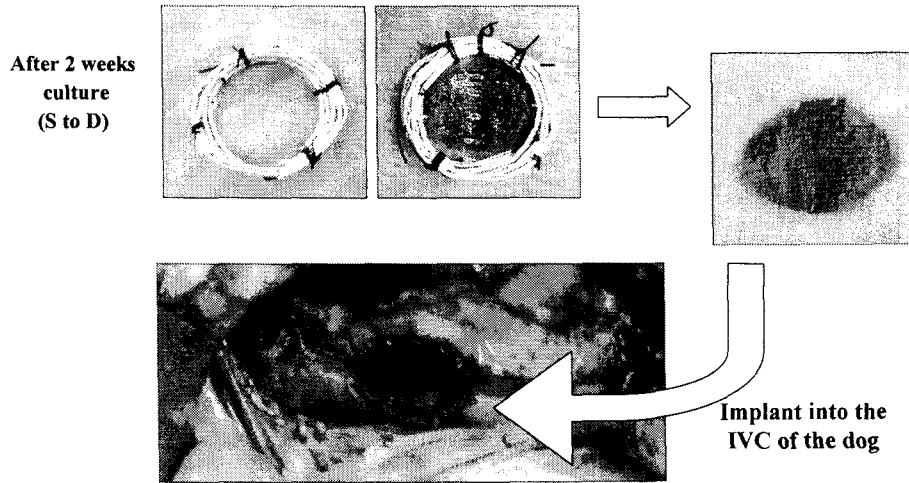
**$\alpha$ -actin immunostain**



**Schematic illustration of tissue engineered vascular graft implantation**



Schematic illustration of tissue engineered  
vascular graft implantation



**Harvest after 1 week implantation**

